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FEASIBILITY STUDY REPORT

JOHNS-MANVILLE DISPOSAL AREA
WAUKEGAN, ILLINOIS

December 1986

(REVISED)

KUMAR MALHOTRA & ASSOCIATES, INC.

ENGINEERS • CONSULTANTS • PLANNERS

Grand Rapids, Michigan

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WAUKEGAN, ILLINOIS

PROJECT: X87-3358

JANUARY, 1986

KUMAR MALHCTRA AND ASSOCIATES, INC.
CONSULTING ENGINEERS
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Manville Service Corporation
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Manville

November 7, 1986

Mr. Brad Bradley
Project Coordinator (5 HE-12)
U.S. Environmental Protection Agency
Region V
230 South Dearborn Street
Chicago, Illinois 60604

RE: JOHNS-MANVILLE WAUKEGAN DISPOSAL AREA RI/FS

Dear Mr. Bradley:

In accordance with the terms and conditions of the Administrative Order by Consent entered into between Johns-Manville Sales Corporation, now Manville Sales Corporation ("Manville"), and the United States Environmental Protection Agency ("USEPA"), Manville is hereby submitting two copies of the Feasibility Study Report on the Johns-Manville Waukegan Disposal Area. This report contains responses to your review comments on the FS report submitted in February, 1986. Copies of review comments and responses have been included in Appendix B. Please feel free to contact me if you have any questions on the contents of this report.

Sincerely,

Marvin Clumpus, P.E.
Project Coordinator

MC/ss

Enclosures

cc: Basil G. Constantelos, USEPA (w/enclosure)
Richard McGraw, USEPA Consultant
Kurt D. Neibergall, IEPA

M
• ENGINEERS • CONSULTANTS • PLANNERS •

KUMAR MALHOTRA & ASSOCIATES

3000 East Belt Line N E
Grand Rapids, Michigan 49505
Telephone (616) 361-5092

November 10, 1986

Mr. Marvin Clumpus, P.E.
Project Coordinator
Manville Sales Corporation
P O Box 5108
Denver, Colorado 80217

RE: Feasibility Study Report, Johns-Manville Disposal Area
Waukegan, Illinois

Dear Marvin:

This Feasibility Study (FS) Report includes responses to USEPA review comments on the February, 1986 FS report. It presents a step-wise identification and evaluation of potentially feasible alternatives for remedial action according to the requirements of the National Oil and Hazardous Substances Contingency Plan (NCP).

A number of remedial action alternatives were evaluated. Considering their technical feasibility, public health and environmental impacts, fulfillment of institutional requirements and present worth costs, the soil covering with vegetation involving a total soil cover thickness of 18 inches is the most desirable alternative for this site. Two variations of this alternative involving soil cover thickness of 24" and 30" respectively were also evaluated. These variations although have public health and environment impacts similar to that of the primary alternative (18" soil cover) but require increased commitment of energy, monetary and other resources. Therefore the soil covering with vegetation alternative involving 18" soil cover thickness is recommended for remedial action at this site. This alternative would provide adequate remedial response and is estimated to have a capital cost of $3,624,170 and an annual O & M cost of $49,000.

If you have any questions on this report please feel free to contact me.

Sincerely yours,

S.K. Malhotra

S.K. Malhotra, Ph.D., P.E.

SKM:sa

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1.0 EXECUTIVE SUMMARY

This document is a Feasibility Study (FS) report for the Johns-Manville Disposal Area, in Waukegan, Illinois. This report presents a step-wise identification and evaluation of potentially feasible alternatives for remedial action according to the requirements of The National Oil and Hazardous Substances Contingency Plan (NCP). This report provides Manville Sales Corporation and USEPA with the information required to select the most appropriate, cost effective and environmentally safe remedial action alternative for the prevention of further contamination and mitigation of existing contamination at the Johns-Manville Disposal Area.

1.1 SITE PROBLEMS AND REMEDIAL RESPONSE OBJECTIVES

Remedial Investigation (RI) studies have shown that Johns-Manville Disposal Area contains lead and asbestos-containing waste materials/soil. Based on monitoring data collected during and after the RI, there is no evidence of off-site migration of any contaminant from the disposal area. Also, no apparent release of contaminants to surface water and/or ground water has been observed. Analysis of groundwater and Lake Michigan water samples showed similar asbestos fiber concentrations. These observed concentrations are similar to those reported in the literature for tap water and commercial beverages. No asbestos fibers, greater than 5 microns in length, were detected in groundwater. The groundwater at the site appears to be of Drinking Water quality. On-site and off-site air quality does not appear to be significantly impacted or degraded by the release of suspended particulate matter or lead. Some of the on-site air samples contained asbestos fibers at levels somewhat higher than those observed at the off-site locations.

Site access is restricted and there are no residential dwellings and drinking groundwater supplies within 0.5 mile radius of the site. Some of the asbestos and lead containing waste materials are exposed at the site and potential of direct contact with the waste by workers and/or wildlife exists. In addition asbestos and lead are subject to airborne dispersal either by routine emissions (e.g., fugitive dust) or through waste disposal activities. Potential for release of lead to groundwater and/or surface water is low.

Therefore the primary objective of a remedial response is to preclude or diminish the potential for on-site airborne asbestos emissions and direct contact with waste materials/soil containing lead.

1.2 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

Technologies that are feasible in immobilizing or destroying/stabilizing asbestos and lead in the waste materials/soil on this site were evaluated. Chemical detoxification, biological treatment, land treatment and incineration technologies were considered non-feasible because of the relatively inert and non-combustible characteristics of the waste materials/soil at this site. Technologies involved in different general remedial response actions (soil covering, capping, on-site treatment/stabilization, on-site landfilling and off-site landfilling) were evaluated for their technical performance, comparative costs, implementability, risk of failure, reliability and potential environmental and public health impacts. This evaluation indicated that a remedial response involving on-site treatment/stabilization is the least desirable from a technology viewpoint because the technology involved is not proven to achieve the objectives, involves high risks, has adverse environmental and public health impacts and is not likely to be acceptable to the neighboring community.

1.3 IDENTIFICATION AND SCREENING OF REMEDIAL ACTION ALTERNATIVES

Seven remedial action alternatives were identified. These were no action, grading and seeding, soil covering with vegetation, soil covering without vegetation, capping, on-site landfilling, and off-site landfilling. Each alternative was evaluated on the basis of its environmental and public health impacts and capital and operation and maintenance costs.

Although the public health and environmental benefits of soil covering with vegetation, soil covering without vegetation and capping are more or less similar, their present worth costs are \$4,086,090; \$4,134,040 and \$7,590,140 respectively. Therefore out of these three alternatives, only the least cost alternative of soil covering with vegetation was used for detailed analysis.

1.4 REMEDIAL ACTION ALTERNATIVES AND ANALYSIS

Four alternatives were devised for mitigating potential adverse impacts of the contaminated materials/soil at this site. A fifth no action alternative was added to fulfill NCP requirements. In addition, two variations of soil covering with vegetation alternative were evaluated. These alternatives are summarized as follows:

- <u>Alternative I: No Action</u>

  Involves leaving the waste materials/soil on the disposal area in their current state, but includes monitoring of groundwater and surface water.

- <u>Alternative II: Grading and Seeding</u>

  Involves grading of waste materials/soil, adding top soil, fertilizing and seeding.

- <u>Alternative III: Soil Covering with Vegetation</u>

  Involves grading of waste materials/soil and laying a minimum of 18" compacted clean soil and top soil cover, fertilizing and seeding. The two variations of this alternative differ only in the use of greater cover soil thickness. One involves a minimum of 24" thick cover and the other 30" thick cover.

- <u>Alternative IV: Off-Site Landfilling</u>

  Involves excavation, removal, transportation and disposal of waste materials/soil in approved off-site landfills.

- <u>Alternative V: On-Site Landfilling</u>

  Involves excavation, removal, transportation and disposal of waste materials/soil in an on-site landfill designed and constructed specifically for the disposal of the waste materials/soil.

These alternatives were evaluated for technical feasibility, institutional requirements, public health and environmental impacts, capital and operation and maintenance costs. This analysis indicated that under the no action alternative potential threat of human and wildlife exposure to lead and on-site airborne asbestos fibers will remain and therefore will not be acceptable to public, local, State and Federal governmental agencies.

Grading and seeding alternative is expected to diminish the potential for on-site airborne asbestos emissions and direct contact with the waste materials. However, this alternative does not meet the NESHAP requirements and may not adequately fulfill remedial response objectives and the requirements of CERCLA. In the short-term, adverse impacts on public health and environment may occur due to construction generated noise, dust and airborne asbestos fibers.

Soil covering with vegetation alternative or its variation is expected to eliminate the potential for on-site airborne asbestos emissions and direct contact with the waste materials. This alternative meets NESHAP and CERCLA requirements. It also provides some protection to groundwater from potential contamination by leachable lead. Its short-term adverse impacts are similar to that of grading and seeding alternative. Soil covering with vegetation alternative involves reduced commitment of energy, money and natural resources as opposed to on-site or off-site landfilling alternatives. The two variations of the soil covering with vegetation alternative although have public health and environment impacts similar to that of the primary alternative but require increased commitment of energy, monetary and other resources.

In the long-term, on-site or off-site landfilling alternative provides adequate protection to groundwater from the contaminants in the waste materials. However, the risk to groundwater from the waste materials/soil at the site is considered low and such protection is not a primary objective of a remedial response for the site. These two alternatives involve relatively longer construction period. In the short-term, both alternatives involve greater adverse impacts on human health and environment due to handling of large quantities of wastes. In addition, the off-site landfilling alternative involves use of scarce commercial landfill capacity and transportation of waste on public roads over long distances. The on-site landfilling alternative, however, involves irreversible use of land currently accessible to wildlife.
On-site and off-site landfilling alternatives involve large commitments of energy, money and other resources and have much higher capital and O & M costs as compared to other alternatives.

1.5 RECOMMENDED ALTERNATIVE

Soil covering with vegetation alternative with a total soil cover thickness of 18" involves readily available and proven technologies to control the source of contaminants. It involves smaller commitment of energy, money and other resources than its two variations involving greater cover soil thickness and can be implemented by the end of 1988. It is estimated to benefit the landscape and wildlife around the disposal area and is likely to be acceptable to neighboring community. This alternative does not depend on the availability of off-site landfill capacity. The short-term adverse impacts on public health and environment due to construction activities are minimal. These adverse impacts are expected to be further minimized through limiting of access, wetting of active construction area prior to grading and waste handling, monitoring workers for exposure to airborne asbestos and using appropriate protective health and safety equipment. This alternative has relatively low capital and O & M costs.

Therefore, soil covering with vegetation alternative involving a soil cover thickness of 18" is recommended for remedial action at Johns-Manville Disposal Area. In addition, provisions of the Superfund Amendments and Reauthorization Act (SARA) of 1986 have been considered and a monitoring program for the soil cover, to be mutually agreed upon by USEPA and Manville, will be developed to attain the new cleanup standards contained in Section 121 of SARA.

2.0 INTRODUCTION

2.1 SITE BACKGROUND INFORMATION

2.1.1 SITE LOCATION AND DESCRIPTION

The Manville Sales Corporation, formerly Johns-Manville Sales Corporation operates a manufacturing waste disposal area adjacent to its manufacturing plant at Waukegan, Illinois. The disposal area covers approximately 120 acres out of the 300 ± acres owned by Manville. The site is located on the shore lines of Lake Michigan in the northeast corner of Waukegan City limits (Figures 2-1 and 2-2). The Waukegan plant site is bounded by Lake Michigan on the east. Illinois Beach State Park on the north, an old city dump site on the west, and a fossil fuel electrical power generating station on the south.

The site consists of solid waste disposal areas and a closed loop process water treatment system. There are currently three active solid waste disposal areas on the southeast area of the site shown in Figure 2-3. These are labelled as asbestos disposal pit, miscellaneous disposal pit and sludge disposal pit. The closed loop water treatment system consists of three separate process water discharges into a series of unlined settling basins (57 acres) with the water returning to the plant via the industrial canal and pumping lagoon along the north side.

2.1.2 SITE HISTORY

Almost all of the solid wastes and process wastewater generated from the manufacturing facility have been treated/disposed on site since 1922. The site is reported to have received asbestos and asphalt containing wastes. These wastes are primarily cuttings and waste products from the manufacturing of asbestos-cement pipe and residues containing roofing and insulating materials. The asbestos in these waste materials is in the encapsulated or bound form. This site has received friable and non-friable asbestos wastes since 1922. The use of asbestos substitutes and changes in product lines have now eliminated the use of asbestos fiber from the manufacturing processes as well as from the manufacturing wastes disposed of at this site. No asbestos is used now in any of the manufacturing processes at the Waukegan Plant. The site has also received small quantities of waste materials containing trace amounts of chromic oxide, lead, thiram and xylene.

Lead was used in the form of lead oxide to produce sheeting materials and is no longer used in the manufacturing process. Thiram, chromic oxide and xylene were used in the past in trace quantities during manufacturing.

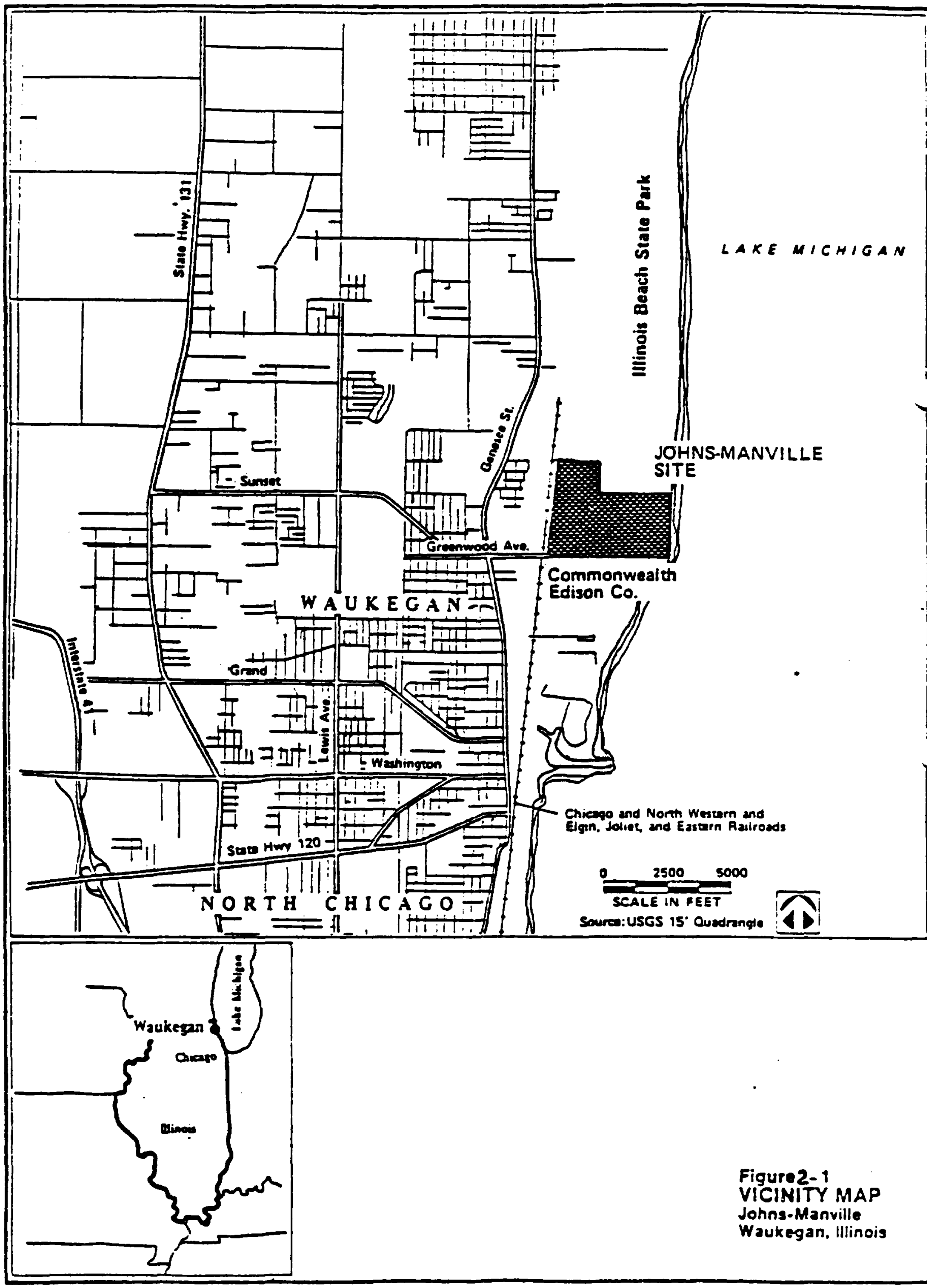
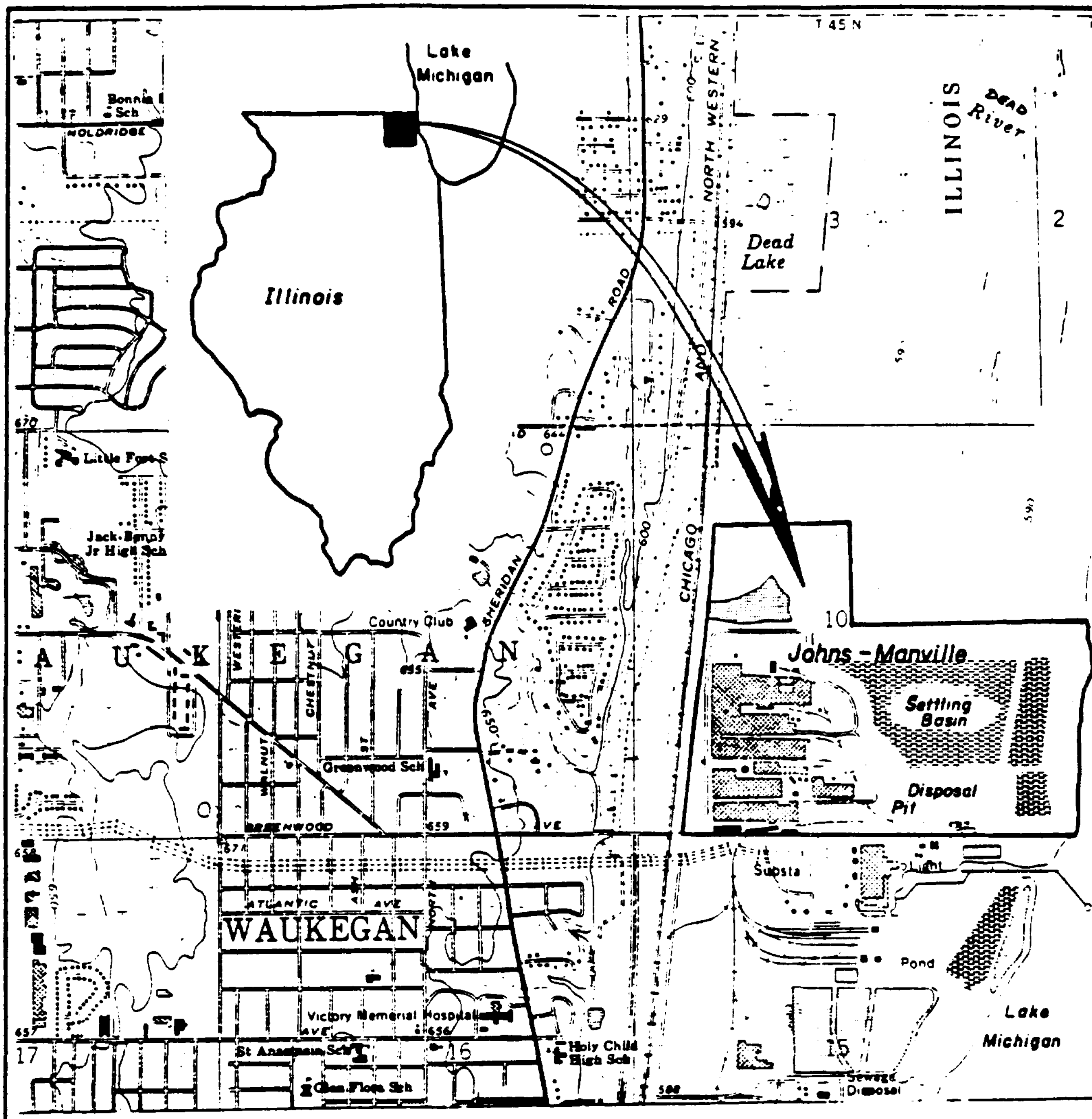


Figure 2-1
VICINITY MAP
Johns-Manville
Waukegan, Illinois



N

1" = 2000'

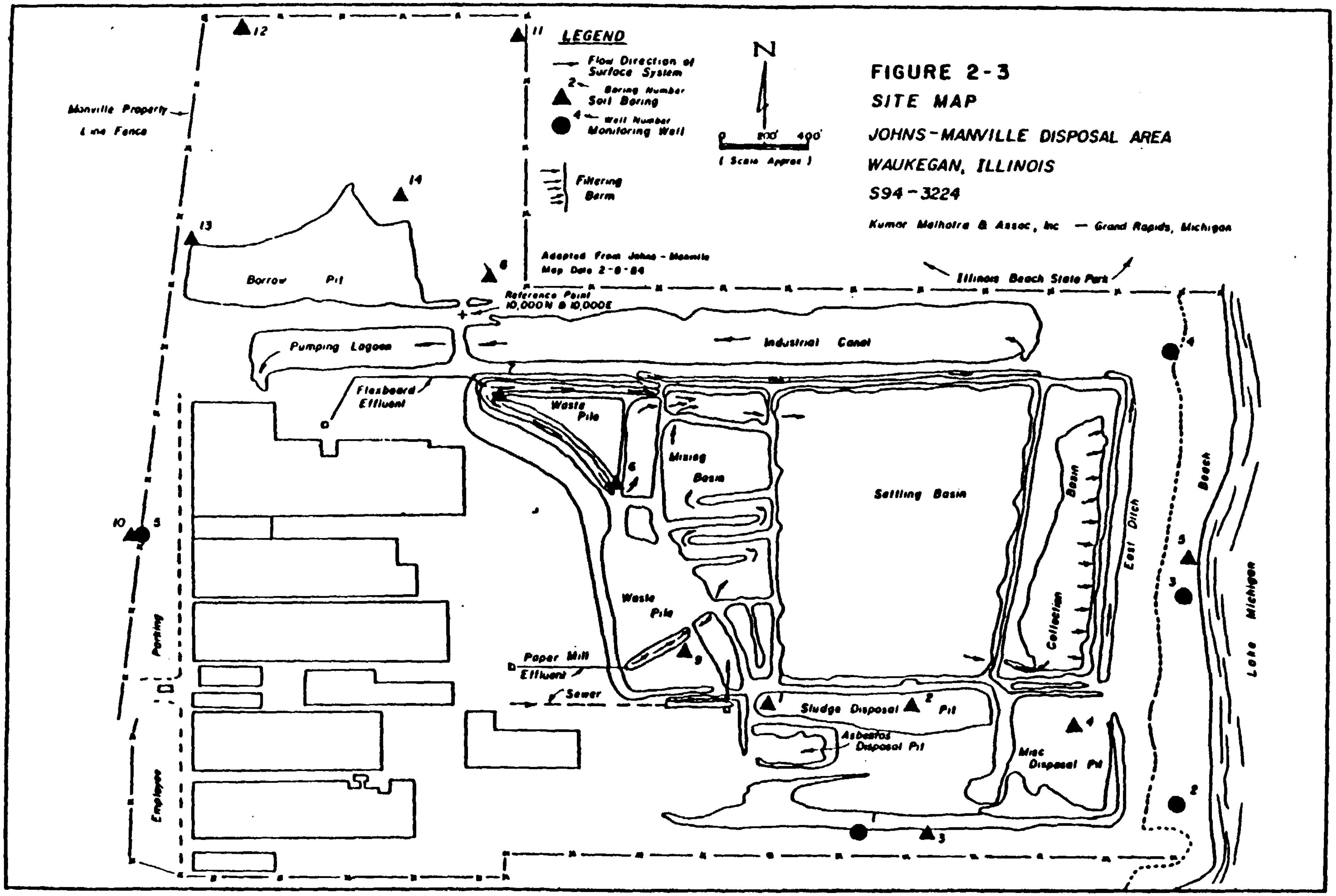
Map adapted from
USGS Zion Quad. Map

1/85

FIGURE 2-2
REGIONAL LOCATION MAP
JOHNS-MANVILLE DISPOSAL AREA
WAUKEGAN, ILLINOIS

S94-3224

Kumar Malhotra & Assoc, Inc. – Grand Rapids, Michigan


LEGEND
Flow Direction of Surface System
Boring Number
Soil Boring
Well Number
Monitoring Well
Filtering Berm
Adapted From Johns - Manville Map Date 2-8-84
N
0 200' 400'
(Scale Approx)
FIGURE 2-3
SITE MAP
JOHNS-MANVILLE DISPOSAL AREA
WAUKEGAN, ILLINOIS
S94-3224
Kumar Malhotra & Assoc, Inc — Grand Rapids, Michigan
Manville Property Line Fence
Borrow Pit
Reference Point 10,000N & 10,000E
Illinois Beach State Park
Pumping Lagoon
Industrial Canal
Flexboard Effluent
Waste Pile
Mixing Basin
Settling Basin
Collection Basin
East Ditch
Beach
Lake Michigan
Waste Pile
Paper Mill Effluent
Sewer
Sludge Disposal Pit
Asbestos Disposal Pit
Misc Disposal Pit
Parking
Employee

The waste materials, generated from the manufacturing processes have been treated/disposed on site. A substantial portion of these wastes has been used to form dikes of the process water treatment basins and waste piles shown in Figure 2-3. The remaining waste materials have been deposited, compacted and covered to form the mounded areas around the currently used waste disposal pits on the south side of the disposal area. The asbestos disposal pit now receives limited quantities of friable asbestos waste from the cleaning/decontamination activities at the Waukegan plant and is managed in accordance with the requirements of National Emission Standards for Hazardous Air Pollutants (NESHAP). The miscellaneous disposal pit receives loose and baled scrap products.

The process water which does not contain any hazardous material is treated by settling and filtration and is recycled. There is no direct discharge of process water to any surface water. The settled inorganic sludge, predominantly lime sludge, from the settling basins is dredged periodically and deposited in sludge disposal pit. Some of the dredged sludge has been used in the past as cover material for the deposited waste piles.

There has been no incidence of explosion or groundwater contamination at this site. There has been a smoldering fire on the disposal area caused by hot glass waste from the refractory insulation manufacturing process. This resulted in some smoldering of wastes and was put out by Manville's waste disposal crew.

Air quality in the vicinity of the site is generally good. Airborne asbestos monitoring was conducted at the facility in 1973 and 1982. The potential suspension of asbestos fiber from the degraded waste materials appeared to be the major concern. This site was included in the National Priorities Listing in 1982 and a Remedial Action Master Plan was prepared in 1983 which recommended carrying out of remedial investigation and feasibility study. Manville contested the basis for this listing. Nevertheless it has entered into a consent agreement with USEPA to conduct a remedial investigation and feasibility study for the site. Remedial investigation (RI) has been completed and final RI report was approved by USEPA in November, 1985.

2.1.3 PHYSIOGRAPHY

At the Johns-Manville site, the local physiographic unit is the Lake Border Morainic System. The general topography surrounding the Johns-Manville site is level. The process buildings are on natural ground. The highest part of the disposal area is about 40 feet above natural ground. The surface topography of the waste area is irregular. In general, peripheral portions of the site slope away from the center of the site. In the vicinity of the wet basins, drainage is to the basins. Part of the south portion of the site slopes into closed depressions, such as the asbestos disposal pit, the miscellaneous disposal pit and the sludge disposal pit. The southwestern portion of the disposal area slopes generally to the west. The southeastern portion of the disposal area slopes generally to the east, towards Lake Michigan.

2.1.4 GEOLOGY

The Johns-Manville facility is situated on an area of unconsolidated glacial drift. Glacial drift at the site ranges from 75 feet to 100 feet in thickness. Significant areas on and around the site are "man made" land. These areas consist primarily of sandy fill over lacustrine sands of Glacial Lake Chicago. The lacustrine sands at the site range from 5 feet to 39 feet in thickness. These sands overlie the clayey Wadsworth Till Member of the Lake Border Moraine System.

The till deposits range in thickness from 50 feet to 75 feet. The Wadsworth Till Member consists of silt-clay-sand matrices of low permeability. A thin sand and gravel deposit underlies the till. This layer ranges from 15 to 30 feet in thickness and is underlain in turn by the bedrock.

The uppermost bedrock consists of Silurian-age Dolomite of the Niagaran-Alexandrian Dolomite. The formation is silty at the base and may locally be cherty. The dolomite has a thickness of up to 300 feet and dips to the east.

A succession of shales, dolomites and sandstones complete the stratigraphic column above the PreCambrian-age Granite. Three of these strata are significant water producing zones. They are the Glenwood-St Peter Sandstone, the Ironton-Galesville Sandstone, and the Mt Simon Sandstone.

2.1.5 HYDROLOGY

The Johns-Manville site is located on the Lake Michigan shore. The lakefront area is subject to storm waves and erosion periodically. Drainage at the Johns-Manville site is primarily collected either in catch basins at the paved areas or in the wet waste basin system and recycled. From the southeast slopes of the site, there may be surface runoff to Lake Michigan.

Water supplies for the City of Waukegan are drawn from Lake Michigan from a location about one mile southeast of the site. After use, this water is returned to Lake Michigan in the form of treated effluent.

2.1.6 GEOHYDROLOGY

Groundwater resources are available everywhere in Lake County. The five major water-yielding units are: the glacial drift aquifers within the lacustrine sands, the shallow dolomite aquifer (Silurian), the Glenwood-St Peter Sandstone, the Ironton-Galesville Sandstone, and the Mt. Simon Sandstone. The two aquifers closest to the surface, the glacial drift and shallow dolomite aquifers, form the shallow system and are replenished or recharged by local rainfall. The remaining three deep sandstone aquifers are recharged by precipitation seeping downward through the overlying rocks on a regional scale.

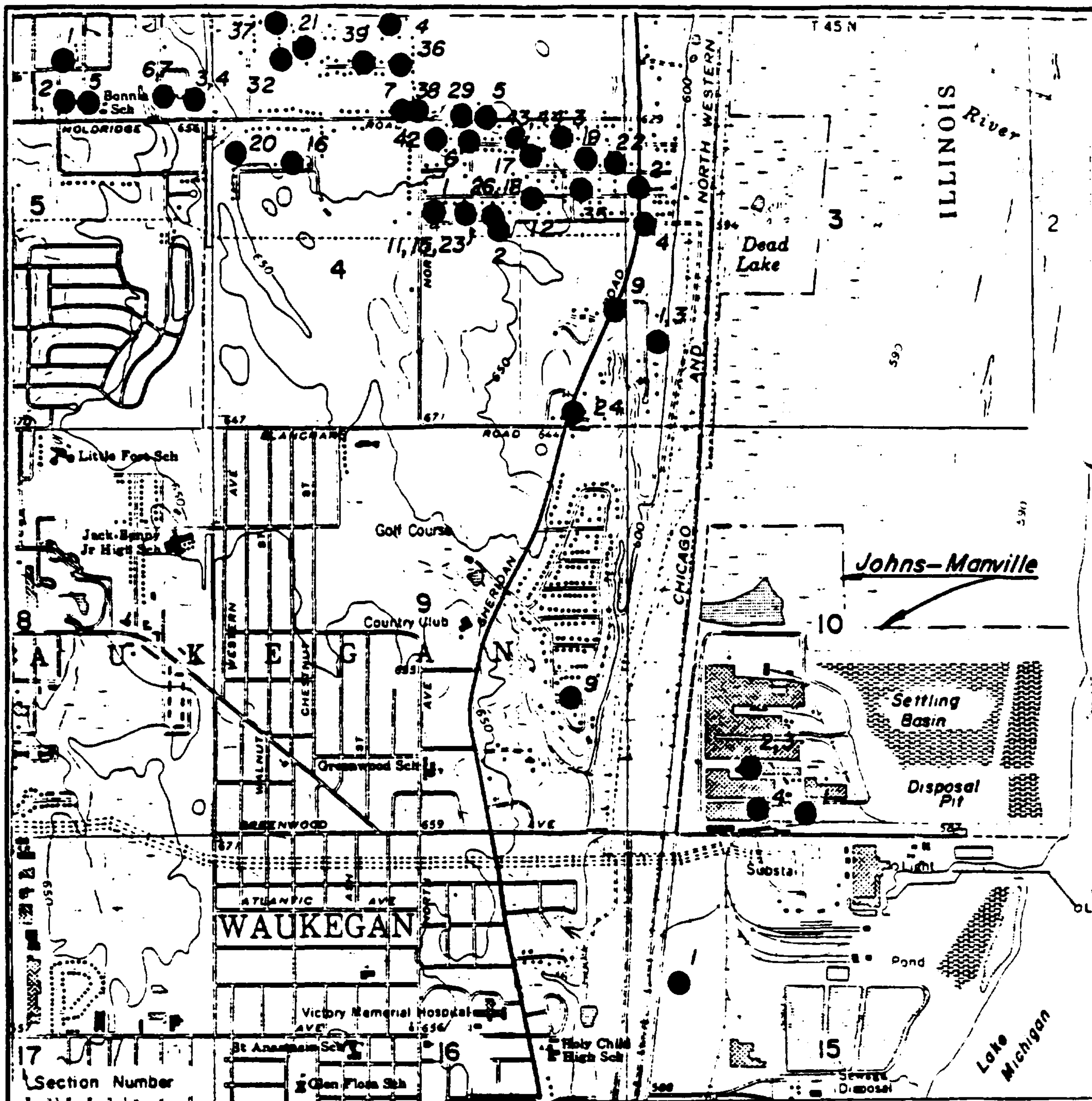
Only those wells with records that could be confirmed by cross checking the locations with other sources are shown on Figure 2-4. All wells in the vicinity of the site are in the Sillurian-age Dolomite or Mt. Simmon Sandstone aquifer and vary in depth from 95 feet to 1620 feet. Some of these wells are used for industrial water. All users in the vicinity of the site are served by city water supply system.

A highly permeable surficial sand layer acts as an unconfined water table aquifer at this site. The lower boundary of this aquifer is a clay layer. Its total saturated thickness ranged from 22 to 37 feet across the site from west to east. The water table was encountered at 1 to 3 feet below the land surface.

The general groundwater movement at the Johns-Manville site is lateral and upward towards Lake Michigan.

2.1.7 ECOLOGY

No wildlife habitat exists on the adjoining south and west sides of the site. Wildlife habitat does exist to the north of the site within a distance of 500 feet from the Manville property line fence and over 2000 feet north of the active waste disposal pits. Wildlife may include



LEGEND

3 — Well Nº Within The Section

● Well Location

N

1" = 2000'

Map adapted from
USGS Zion Quad Map
1/85

FIGURE 2-4
WELL LOCATION MAP
JOHNS-MANVILLE DISPOSAL AREA

S94-3224

Kumar Malhotra & Assoc., Inc. – Grand Rapids, Michigan deer, squirrel, ruffled grouse, ring neck pheasant, cottontail rabbit and small rodents. In addition, the industrial canal on the north side of the site and Lake Michigan on the east side does attract wild ducks and migratory birds.

Lake Michigan on the east side of the site and cooling water ponds of Commonwealth Edison Company on the southeast side of the site are recreational fishing bodies of water.

No adverse impacts of Manville waste disposal activities have been reported on the vegetation, birds and wildlife in the vicinity of the site.

2.1.8. SOCIOECONOMICS

The Johns-Manville disposal area is located in the industrial belt along the eastern edge of the City of Waukegan. There is no residential dwelling within 1.0 km radius of the site. There are approximately 200 homes within 1.0 mile radius of the western edge of the site.

Within 1.0 mile radius of the site the number of persons estimated to be present during the day-shift is 4,750 and night-shift is 2,225. Approximately 20 percent of these are area residents and 80 percent industrial and commercial workers.

Most of the residential homes are located northwest of the site and are inhabited by moderate income families. The residential property values as well as renter occupancy and rental values in the vicinity of the site have been keeping pace with inflation and values in other residential areas of the city. There has been no documented adverse impact on the tourism and recreational activity in the vicinity of the site or in Lake County.

2.1.9 COMMUNITY PERCEPTION

The public interest and involvement in this site have been minimal. The City of Waukegan, the Lake County Health Department and County Environmental Organization (Lake County Defenders) have expressed interest in the site. The expressed concern has been the potential of airborne asbestos in the immediate vicinity of the site.

2.1.10 PLANNED USE OF SITE

The City of Waukegan Master Plan indicates an open corridor along the lakefront that includes this site. The City's long range goal is to use the site for public recreation. Manville however, plans to continue its present use.

2.2 NATURE AND EXTENT OF PROBLEM

2.2.1 WASTE CHARACTERISTICS AND QUANTITIES

There are basically three types of wastes present at this site. These are the process water, the manufacturing waste materials, and the wet and dried sludge collected in process water settling basins. Each is described below:

Process Water

About 4.4 mgd of relatively alkaline process water containing lime precipitates is treated at this site and recycled through the plant. In the past the process water flow has been as much as 10.0 mgd. The process water does not appear to contain any hazardous substance. Approximately half of the 120-acre disposal site is occupied by process water settling and filtration basins (see Figure 2-3).

Manufacturing Waste Materials

These are waste cuttings and ashes from the manufacturing of roofing materials, pipes, insulating and miscellaneous products. These wastes comprise the majority of the remaining 120-acres disposal area including the dikes of the process water treatment basins. Some of these waste materials contain encapsulated asbestos, lead oxide, chrome oxide and trace quantities of coal tar derivatives. None of these ingredients appear to be readily releasable to the environment. However, asbestos fibers could be released during crushing and leveling of some of these materials. Many of the piles of waste materials are covered with clean soil and sludge removed from the process water settling basins. There are about 2,000,000 ± cubic yards of manufacturing waste materials deposited on this site and about 80 cubic yards are being deposited now in the miscellaneous disposal pit (Figure 2-3) on a typical working week-day.

In addition limited quantities of waste materials containing friable asbestos from the cleaning/decontamination activities at the plant are deposited in the asbestos disposal pit (Figure 2-3). These are bagged, labelled and covered with clean soil. There are about 25,000 ± cubic yards of such waste materials deposited on this site.

Process Water Sludge

This is the sludge removed from the process water settling basins and deposited in the sludge disposal pit and on piles of manufacturing waste materials. There are about 175,000 ± cubic yards of sludge deposited at this site and about 50% of this is deposited in the sludge disposal pit and about 50,000 ± cubic yards is estimated remaining in the settling basins. The remaining 37,500 ± cubic yards of sludge is deposited on piles of manufacturing wastes. About 800 to 1,000 cubic yards of sludge is being deposited in the sludge disposal pit annually. The sludge is predominantly non-biodegradable lime sludge. Some of it contains chrome, lead and asbestos, but none of these contaminants were observed to be readily releasable to the environment. When the sludge dries out, there is a potential of release of asbestos to the atmosphere. Asbestos dust/fiber could also be released during excavation and handling of the dried sludge. However, the bound nature of the asbestos in the sludge reduces potential asbestos fiber releases from the dry sludge.

2.2.2 PRESENT CONDITION OF DEPOSITED WASTE MATERIALS

The top surface of the manufacturing waste materials deposited at this site are covered by combinations of process water sludge, clean soil and road gravel. The majority of the sloped surfaces of the banks of waste materials are not covered with clean fill except those on the south and east edges of the disposal area. The deposited waste sheeting materials and asbestos-cement pipe pieces are exposed at majority of the dike slopes. Settling basins have varying depths of sludge and process water. There is a significant amount of shrubbery and vegetation growth on the surface and side slopes of the deposited waste piles.

2.2.3 SOIL CONDITION

Surface, near-surface and sub-surface soil sampling sites evaluated during remedial investigation are shown in Figure 2-3. Bulk asbestos content observed was below the limit of quantification (less than 1.0 percent). Thiram was not detected. Chromium levels were low, mostly less than 30 mg/kg. However, lead levels were relatively high. Some values between 1,000 and 4,700 mg/kg were found in areas (of Soil Boring # 1,2,3,4 & 6) where solid wastes have been disposed. These levels of lead were encountered at varying depths and no definite layering pattern was observed. Lead levels in the off-site soil samples were very low, mostly less than 20 mg/kg. Organic contaminant levels were relatively very low.

2.2.4 GROUNDWATER AND SURFACE WATER CONDITION

The location of groundwater and surface water monitoring is shown in Figure 2-5.

The soil and well boring data indicated that underneath the deposited wastes is an unconfined water table aquifer, 22 to 37 feet thick, from west to east of the site. This aquifer lies over a clay layer which is reported to be over 50 feet thick and dips from west to east into Lake Michigan. The observed hydraulic conductivity of the sands in this aquifer ranged from 46.6 ft/day to 73.4 ft/day and the groundwater at the site ultimately moves eastward to Lake Michigan. Seepage from the treatment basins is normal (about 1/4 inch per day) and is not estimated to migrate in the northerly direction away from the service water recycling basins.

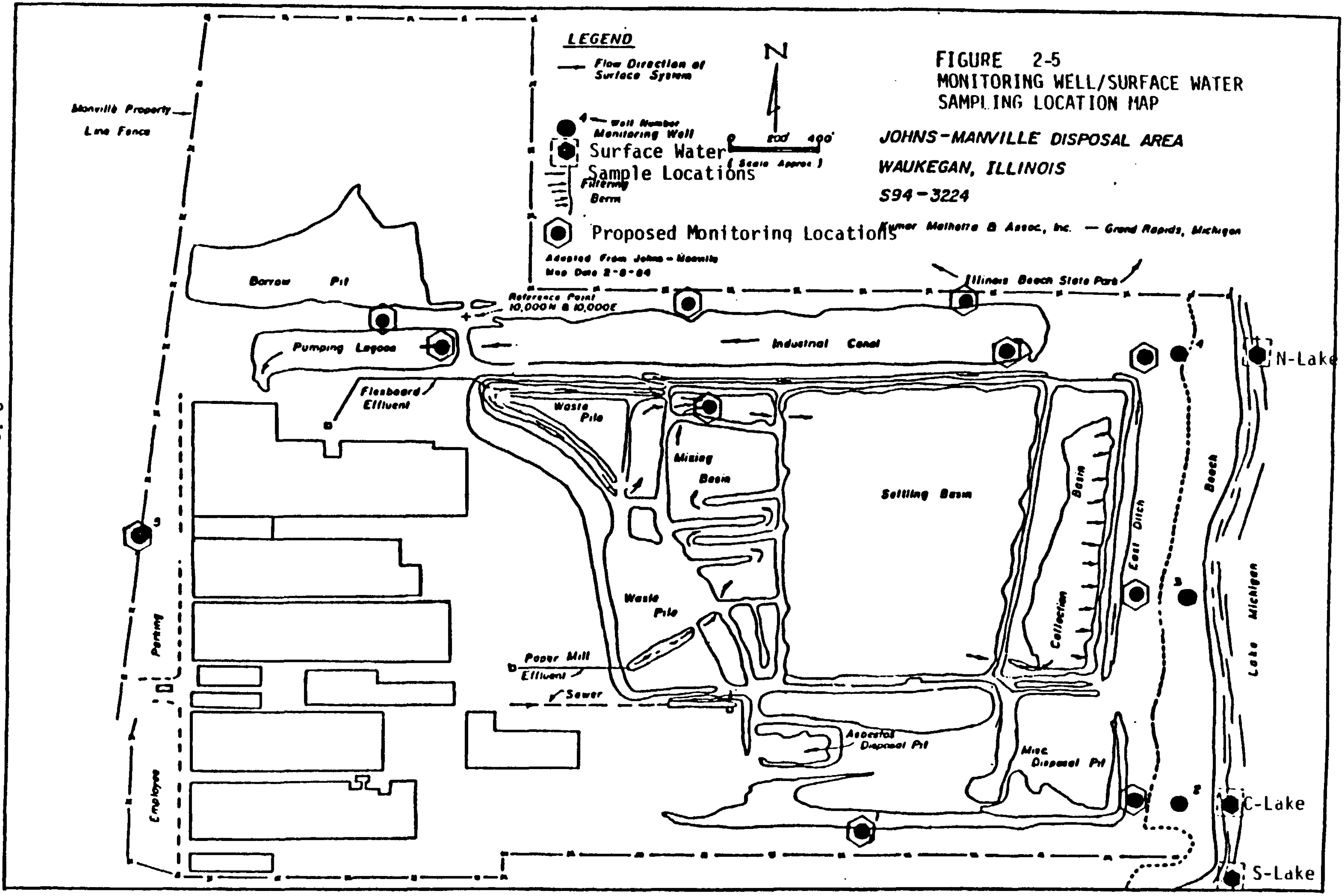
Traces of lead, barium, copper, arsenic, boron, iron, manganese and zinc were detected in some of the well samples. All these compounds as well as chlorides and sulfates were present in levels below the drinking water standards. No organic contaminants were observed. Analysis by electron microscopy identified presence of asbestos in the range of 6 to 12 million fibers per liter in the well water samples and 5.5 to 19 million fibers per liter in the Lake Michigan water samples. Asbestos fibers greater than 5 microns in length were not detected in the groundwater samples, and the highest observed value from all the surface water samples was 1.2 million fibers per liter.

2.2.5 AIR QUALITY

On-site and off-site locations were used for air sampling for asbestos fiber counts, lead and total suspended particulates (TSP). The nearest off-site location was in the residential area closest to the site, approximately 1.0 mile from the site.

Samples for asbestos monitoring were analyzed by transmission electron microscopy. The majority of fiber concentrations were close to the detection limit, although some on-site values were higher than off-site values. In terms of fibers longer than 5 micrometers, all concentrations were at or very close to the detection limit (0.003 fibers/cubic centimeter).

All on-site observed values for lead were less than 0.08 ug/m^3. These are significantly lower than those (0.2 to 0.3 ug/m^3) observed by Division of Air Pollution Control, Illinois EPA in the residential and commercial areas of Lake and Cook Counties. The highest observed value of


LEGEND
Flow Direction of Surface System
Well Number
Monitoring Well
Surface Water Sample Locations
Filtering Berm
Proposed Monitoring Locations
Adapted From Johns-Manville Map Date 2-8-84
N
0 200 400'
(Scale Approx.)
FIGURE 2-5
MONITORING WELL/SURFACE WATER SAMPLING LOCATION MAP
JOHNS-MANVILLE DISPOSAL AREA
WAUKEGAN, ILLINOIS
S94-3224
Kumar Malhotra & Assoc., Inc. — Grand Rapids, Michigan
Manville Property Line Fence
Borrow Pit
Reference Point 10,000N & 10,000E
Illinois Beach State Park
Pumping Lagoon
Industrial Canal
N-Lake
Flexboard Effluent
Waste Pile
Mixing Basin
Settling Basin
Collection Basin
East Ditch
Beach
Lake Michigan
Paper Mill Effluent
Sewer
Asbestos Disposal Pit
Misc. Disposal Pit
Parking
Employee
C-Lake
S-Lake

0.107 ug/m^3 of lead was at an off-site location. This value is one order of magnitude smaller than the National Ambient Air Quality Standard (NAAQS) of 1.5 ug/m^3

The observed TSP values ranged between 7.2 ug/m^3 and 104.0 ug/m^3. All TSP values were less than 24-hour maximum values of 260 ug/m^3 (Primary NAAQS), and 150 ug/m^3 (Secondary NAAQS).

2.2.6 RISK ASSESSMENT

Site access is restricted and there are no residential dwellings and groundwater drinking supplies within 0.5 mile radius of the site.

The site has some soil contaminated with relatively high levels of lead. However, due to the alkaline nature of the wastes disposed at the site, the lead does not appear to be readily releasable to the environment. Total suspended particulates and lead levels in the on-site ambient air are relatively low, and therefore potential of human and animal exposure to lead through fugitive dust appears to be low.

Airborne asbestos fiber concentrations on-site, for fibers of all lengths, are somewhat higher than off-site. However, all concentrations for fibers longer than 5 microns are at or near the detection limit (0.003 fibers/cc). Manville Sales Corporation employees working on and around the waste disposal area, persons using recreational facilities near the disposal area, and wildlife harboring in the vicinity of the site could be exposed to very low levels of airborne asbestos fibers.

The observed levels of asbestos fiber (5.5 to 19 million fibers per liter) in the surface water and groundwater in the vicinity of the disposal area are similar to those reported in the literature for tap water and commercial beverages. Futhermore, asbestos fibers greater than 5 microns in length were not detected in groundwater and the observed values in the surface water were in the range of 0.2 to 1.2 million fibers per liter. These values are well below EPA's recently proposed RMCL for asbestos in drinking water. No carcinogenic or other effects have been demonstrated to result from injestion of asbestos fibers in food or water supplies, and there are no known effects of ambient asbestos fibers on non-human species. The probable exposure to asbestos fibers of human and non-human population is low. It is unlikely that the asbestos from this site would threaten the use of Lake Michigan by area residents for recreation and other purposes.

The groundwater at the site appears to be of drinking water quality in spite of many years of waste disposal activities at the site. The groundwater appears to move ultimately towards east to Lake Michigan.

Based on monitoring data collected during and after the RI, there is no evidence that the contaminants are migrating from the site.

The off-site migration potential of contaminants from the site is low. The site does not appear to threaten the existing or future uses of Lake Michigan water, groundwater, air, and other environmental resources in the vicinity of the site.

Therefore, the exposure potential and intended risk to human health and environmental resources in the vicinity of the site is considered low.

2.2.7 SITE CONTROL ACTIONS AND THEIR BENEFITS

The friable asbestos wastes are covered with 6" clean soil cover within 24 hours of dumping. Other solid wastes are graded and compacted at least once per week. Bermed disposal pits are used to minimize wind blowing paper and other light materials. Cyclone fencing is used to control public access. Dust from the unpaved roads is suppressed by sprinkling water at least once per week during the summer months. Some of the waste materials deposited at this site have been covered with clean soil and seeded. The combined benefits of these activities are believed to be the low levels of on-site airborne contaminants and the apparent absence of off-site contaminant migration.

2.3 PURPOSE AND OBJECTIVES OF REMEDIAL ACTION

The National Oil and Hazardous Substances Contingency Plan (40 CFR 300) requires a step-wise identification and evaluation of potentially feasible alternatives for remedial action at Superfund sites. The purpose of this feasibility study is to perform these analyses, thereby providing Manville and USEPA with the information required to select the most appropriate, cost-effective, and environmentally safe method(s) for the prevention of further contamination and mitigation of existing contamination at this site.

No initial remedial measures are warranted as there are no apparent releases of contaminants which pose any immediate threat to human health, welfare or environment in the vicinity of this site.

No release of contaminants into the environment is observed from the waste disposal area except limited amounts of asbestos fibers into the ambient air. Further, these releases have been very low and limited based on the data collected during the RI.

Based on monitoring data collected during and after the RI, there is no evidence of off-site migration of any contaminant from the waste disposal area. Also, no apparent release of contaminants to surface water and/or groundwater has been observed. Therefore, the primary objective of the remedial action is to secure the on-site waste materials to eliminate or minimize direct contact and airborne dispersion pathways.

2.3.1 ENVIRONMENTAL CRITERIA FOR REMEDIAL ACTION

In consideration of the potential exposure pathways at this site a number of site specific assumptions and environmental criteria have been selected. These are as follows:

- Since the majority of the 2.2 million cubic yards of waste materials deposited are heterogeneous in nature, it is assumed that all waste materials and residues on the disposal area contain varying levels of asbestos and lead and will need securing. It is further assumed that release of asbestos to the air can occur during grading and removal of the waste materials.

- 24" cover of compacted clean soil without vegetation or 6" cover with vegetation is considered adequate to meet the objective of minimizing direct contact and airborne dispersion pathways (40 CFR 61.153), especially since virtually all the waste materials are in encapsulated or bound form Freeze-thaw effects can result in the upward movement of asbestos-containing objects. A minimum of 18" cover with vegetation will be considered adequate (see upfreezing cover thickness analysis report presented in Appendix C) to meet the objective of minimizing direct contact and airborne dispersion pathways because of the freeze-thaw effects. In addition, provisions of SARA have been considered and a monitoring program for the soil cover to be mutually agreed upon by USEPA and Manville, will be developed to attain the new cleanup standards contained in Section 121 of SARA.

- Any off-site soil containing less than *40 mg/kg of lead and less than 1% bulk asbestos will be considered non-polluted.

(* April 1977 USEPA Dredged Spoil Disposal Criteria Classification Guidelines For Great Lake Harbors)

- EPA's recently proposed (Federal Register November 13, 1985) RMCL for asbestos in Drinking Water of 7.1 million fibers per liter (for medium and long fibers i.e. greater than 10 microns in length Chrysotile asbestos fibers) is selected for non-contaminated water.

- Surficial contaminated soil above the water table represents a secondary source of groundwater contamination. Lead contained in these soils does not pose a significant threat to groundwater resources because of its relative immobility under existing alkaline conditions and the bound nature of lead in the waste materials.

- Sub-surface soil below the water table is not perceived to be a contamination source based on the RI sampling and its removal below the water table will not aid in accomplishing the objectives of this feasibility study.

3.0 REMEDIAL ACTION ALTERNATIVE IDENTIFICATION

3.1 SITE PROBLEMS AND GENERAL RESPONSE ACTIONS

Detailed site investigations have shown that some of the manufacturing wastes disposed on the waste disposal area contain asbestos and lead. However, these contaminants appear to be bound to other inert manufacturing ingredients in such a way that these are not being released to the groundwater. On-site and off-site air quality does not appear to be significantly impacted or degraded by the release of suspended particulate matter or lead. Some of the on-site air samples contained asbestos fibers at levels somewhat higher than those observed at the off-site locations.

Some of the asbestos and lead containing waste materials are exposed at the site and potential of direct contact with the waste by people and/or wildlife exists. In addition asbestos and lead are subject to airborne dispersal either by routine emissions (i.e., fugitive dust) or through waste disposal activities. However, there has been no apparent release of contaminants to surface water or groundwater.

Therefore the primary purpose of a remedial action program is to preclude or diminish the potential for on-site airborne asbestos emissions and direct contact with waste materials/soil containing lead. A range of potential alternative remedial response actions to secure the waste materials deposited on the site and to eliminate or diminish future exposure pathways are as follows:

- No action
- Soil covering
- Capping
- On-site treatment/stabilization
- On-site disposal/landfilling
- Off-site disposal/landfilling

3.2 IDENTIFICATION AND SCREENING OF ALTERNATIVE TECHNOLOGIES

A feasible technology for Johns-Manville Waukegan Site is one which will immobilize or destroy/stabilize asbestos and lead in the waste materials and soil on this site such that the potential of asbestos releases to the air and direct contact with lead contaminated materials is eliminated or minimized.

Surface and near surface waste materials at this site, the most likely control targets, are relatively non-combustible and relatively inert. Therefore, based on the above criteria and the characteristics of the waste materials/soil, technologies like chemical detoxification, biological treatment, land application and incineration are considered to be not feasible at this site. Remedial technologies considered feasible for each response action, to address the primary concerns at this site are summarized below:

1. Soil Covering

   - Clearing and grubbing
   - Grading wastes
   - Placing clean soil cover
   - Placing riprap on pond slopes and gravel on roadways
   - Placing top soil and constructing site drainage ditches
   - Revegetation with grasses and shrubs

2. Capping

   - Clearing and grubbing
   - Grading wastes
   - Placing multi-layered cap and placing synthetic liner in settling basins
   - Placing riprap on pond slopes and gravel on roadways
   - Revegetation with grasses and shrubs

3. On-site Treatment/stabilization

   - Clearing and grubbing
   - Grading and segregating wastes
   - Placing clean soil cover
   - Mixing soil with lime, cement and water
   - Spreading and compacting of soil mixtures
   - Cement grouting of steep slopes

4. On-site disposal/landfilling

   - Developing area for landfill construction by grading and preparing subbase
   - Installing multi-layer liner

- Excavating and removing wastes to landfill; collecting and treating leachate and runoff

- Placing multi-layered cap and closing landfill

- Rebuilding of process water treatment basins and backfilling and grading of site

5. Off-site disposal/landfilling

   - Excavating, testing and removing wastes to "roll off" boxes

   - Transporting to approved disposal facilities

   - Rebuilding of process water treatment basins and backfilling and grading of site.

While each of the technologies outlined above has some applicability at this site, several factors suggest that the range of appropriate options is more restricted. The following sections describe the alternative technologies involved in each of the response actions, including their relative merits in accordance with the following evaluation factors:

- Technical performance including ability to satisfy environmental standards

- Comparative cost

- Implementability

- Risk

- Reliability

- Potential environmental impacts including safety

Table 3-1 summarizes, in matrix format, the relative merits of alternative technologies in responding to the primary concerns at this site using a numerical designator for the least favorable to most favorable response. Scores of 0 and 4 in the tables represent the extremes for the alternatives; 0 is the least favorable and 4 is most favorable. Intermediate values between 0 and 4 are used to rate an alternative response in comparison to the other alternatives for related evaluation factors. Intermediate values are subjective, based on experience and engineering judgment. The basis for the scoring applied in Table 3-1 is described in the following paragraphs.

3.2.1 SOIL COVERING AND CAPPING

Soil covering technology alternative involves construction of a soil cover over the waste materials deposited at the site. In addition, a minimum cover of 24" clean soil on all roadways with an additional 4" to

TABLE 3-1

RELATIVE MERITS OF ALTERNATIVE TECHNOLOGIES
CONTROL OF WASTE SOURCES(1)

EVALUATION FACTOR	CRITERIA	SOIL COVERING(4) A	SOIL COVERING(4) B	CAPPING	ON-SITE STABILIZATION	OFF-SITE DISPOSAL	ON-SITE(3) DISPOSAL
		ALTERNATIVE SCORE(2)					
Technical Performance Including Ability To Satisfy Environmental Standards	Proven Technology	2	2	3	0	4	3
	Degree of Ground Water Protection Provided	1	0	3	2	4	3
	Elimination of Direct Contact and Airborne Dispersion Pathways	4	4	4	0	4	4
Comparative Cost	Capital Cost	3	4	2	3	0	1
	Operation and Maintenance Cost	4	3	3	1	0	2
	Cost Certainty	4	4	2	1	0	1
Implementability	Effort Required for Design/Approval	4	4	3	1	2	0
	Time Required to Implement and achieve beneficial results	3	4	3	1	1	0
	Constructability	4	4	3	1	1	0
Risk	Long-Term Liability	1	1	2	0	4	3
Reliability	Risk of Failure	1	1	2	0	4	3
	Operation and Maintenance requirements	3	3	3	1	4	0
Environmental Impacts Including Safety	Future Site Use	3	3	3	0	4	3
	Potential Health/Env Impacts During Construction	3	4	3	2	0	1
	Public Acceptance	3	3	4	0	1	2
TOTAL SCORE		43	44	43	13	33	28

(1) Sources defined as waste materials containing asbestos and lead.
(2) Legend (relative scores):
    4 -Most Favorable
    3 - Favorable
    2 - Intermediate
    1 - Unfavorable
    0 - Abortive
(3) Assumes facility/system concurrently developed to handle contaminated soils.
(4) Subalternative A - Minimum 24" cover without vegetation
    Subalternative B - Minimum 18" cover with vegetation

8" thick gravel on all-weather dike roadways, nominal 12" thick riprap on 4" bedding material on interior slopes of settling basins and groundwater and surface water monitoring are included in soil covering and capping response alternatives. Two sub-alternatives are permitted relative to thickness of soil cover (40 CFR Part 61.153):

1) Using a minimum of 24" compacted clean soil cover without vegetation.

2) Using a minimum of 6" compacted clean soil cover with vegetation. However, because of the freeze-thaw effects the minimum clean soil cover thickness with vegetation considered adequate is 18"

Capping technology involves multi-layered cap over the waste materials and a synthetic liner in the settling basins which is relatively impermeable. Multi-layer cap involves 30 mils thick synthetic liner, 12" thick sand and gravel flow zone for flowing away of infiltration water and 12" topsoil cover with vegetation.

All of these alternative technologies will provide elimination of direct contact and airborne dispersion pathways and are readily available and straight forward technologies. The typical advantages of 18" soil cover with vegetation, as compared to 24" soil cover without vegetation, and capping, are reduced capital cost, time required to implement and short-term environmental impacts because of relatively reduced material handling. Soil covering sub-alternative technologies provide limited groundwater protection (relative to capping) which, however, does not appear to be of primary concern at this site. Effort required for design and approvals is similar for the two soil covering sub-alternative technologies but is significantly less than that required for capping, on-site and off-site land filling and on-site stabilization technologies. Off-site landfilling technology normally does not need significant design/approval effort. However, the large volume of waste materials to be removed for disposal will require significant effort in planning waste removal as well as in finding enough landfill capacity within reasonable hauling distance. The soil covering sub-alternative technologies involve somewhat greater long-term risks because of the greater vertical migration of precipitation and absence of a liner beneath the waste materials to prevent future migration of lead into the groundwater. Such risks however are minimal at this site due to the bound nature of lead in the waste materials.

Much of the total inventory of waste and contaminated materials at this site need not be moved for implementing soil covering and capping technologies, thereby decreasing potential airborne asbestos emissions and accidents resulting from waste material handling.

3.2.2 ON-SITE TREATMENT/STABILIZATION

Many types of contaminated waste materials and soils can be effectively treated or detoxified using physical, chemical, or biological techniques. At the Johns-Manville Waukegan site, the heterogeneity of the waste materials suggest that on-site treatment techniques may have very limited applicability. Technology is not readily available to remove asbestos and lead contaminants from the waste materials/soil.

The waste materials encountered at the surface and near surface of the disposal area are mainly non-combustible and inert. These can be mixed with clean soil, lime and cement and stabilized to form a relatively stable cover which will minimize potential direct contact and airborne dispersion pathways. The heterogeneous waste materials, especially in the dike slopes of settling basins, do not appear to be amenable to lime and cement-soil stabilization but appear amenable to stabilization by cement grouting.

To implement this stabilization technology, a complex (and costly) on-site waste segregation and processing system would be necessary. Materials that could not be stabilized would be sent to the on-site miscellaneous waste disposal pit. A very significant engineering design and testing program would be required and the time of implementation may be relatively lengthy. On-site stabilization technology alternative is estimated to cost more than soil covering with vegetation but less than capping technology alternative.

The long-term risks of stabilization technology alternative are more than that of other alternatives. Failure of on-site processing systems would result in large quantities of materials being delivered to off-site facilities or use of other technologies. Future site use may be relatively encumbered.

Lime and cement soil stabilization will require disturbing and processing of surface soil and is likely to result in enhanced levels of airborne asbestos on a temporary basis. In addition, the excessive steep slopes at the site are not very amenable to lime and cement-soil stabilization and will require more costly cement grouting. Because materials will be processed at the site, the enhanced risk of accidents due to stabilization work on steep embankment slopes, and the routine releases of environmental contaminants present significant short term concerns. On-site stabilization will involve processing of surficial soils and hence increase potential of higher levels of airborne contaminants and noise in the vicinity of the site. Therefore, some public opposition to on-site stabilization of wastes could also be expected.

3.2.3 ON-SITE DISPOSAL/LANDFILLING

In this technology alternative, the contaminated waste materials/soil present at the site would be excavated, loaded and transported to an on-site landfill designed and constructed specifically for the disposal of Johns-Manville Waukegan waste materials. In addition, the process water treatment basins would have to be reconstructed using clean soil dikes and two feet thick relatively impermeable compacted clay liner. Using this approach about 46 acres in the northwest corner of the Manville Waukegan Plant Property would be developed for construction of a landfill compliant with all applicable regulations, and the site waste materials/soil would be removed from its present location to this landfill. This alternative uses proven technology for contaminated wastes and soil disposal.

The on-site disposal technology alternative is typically considered attractive when the following conditions apply:

- The quantity of waste and contaminated soil is sufficiently large to justify the design, permitting, and facility construction costs.
- The type of waste is conducive to landfilling (e.g., residual solids and contaminated soils).
- The geologic setting is favorable (e.g., approximates that of available commercial facilities) relative to the degree of long-term waste isolation that can be effected.

At this site, the quantity of waste materials/soil (about 2.2 million cubic yards) is relatively large so that the development of an on-site landfill for these materials alone is cost-effective.

Site wastes are amenable to landfilling in an on-site or off-site landfill.

Relative to other available commercial facilities, the geologic and hydrogeologic conditions at this site are not optimum for landfill development. However, the utilization of acceptable engineering practices (i.e., dual liner system, above grade construction) does not preclude the feasibility of an on-site landfill technology.

The presence of very permeable surficial soils overlying a shallow aquifer indicates that a traditional below-grade landfill could not be employed at this site. Such a facility would need to be constructed above grade and should include a dual liner system to minimize off-site contaminant migration. Use of this design would provide a degree of long-term waste isolation similar to that available from commercial landfills.

The capital cost of an on-site landfill technology alternative is estimated to be less than that for the off-site disposal alternative. Long-term monitoring and maintenance costs would be higher than other alternatives but still less than that of off-site disposal alternative because of higher off-site disposal costs of currently generated waste materials.

The design effort required for the on-site disposal technology alternative would be much greater than that needed for the off-site disposal alternative. Detailed design of the landfill must account for management of runoff and leachate both during construction and after the landfill is completed. Testing of liner and cap materials would be needed to assure compatibility with waste materials so that the desired degree of long-term isolation could be achieved. Attainment of all required permits for the landfill would also involve a significant engineering effort.

The engineering efort would delay implementation, as compared to the off-site disposal alternative and the actual construction period would be longer.

Construction of the landfill, waste removal and disposal, closure and reconstruction of the settling basins would require at least four construction seasons as opposed to two needed for soil covering or capping.

Waste disposal in a properly designed and constructed on-site landfill would involve no greater long-term risk than disposal in a comparable off-site facility. However, presence of permeable surficial soils overlying a shallow aquifer does increase risk of potential drinking water source contamination, in case of a liner failure in the on-site landfill. Land use would be restricted in the landfill area but more land would be available along the Lake Michigan shore because of the removal of deposited waste materials.

Future manufacturing waste materials, would be disposed in an off-site landfill or else a portion of the on-site landfill would be kept active.

Short-term potential environmental impacts during construction would be increased, as compared to the off-site disposal alternative, because of air and noise pollution associated with moving larger amounts of materials. However, the transportation of wastes would be greatly reduced, thereby decreasing risks associated with transportation accidents. On-site landfilling will result in air and noise pollution due to moving of large amounts of contaminated material closer to the existing residential dwellings. Therefore, some public opposition to an on-site landfill technology alternative would be expected.

3.2.4 OFF-SITE DISPOSAL/LANDFILLING

This technology alternative involves similar on-site waste/soil excavation and handling as used in the on-site disposal alternative. The difference is that existing commercial landfills at off-site locations would be used for disposal of solid wastes and contaminated soils. Future manufacturing wastes, would be disposed in an off-site landfill. This alternative relies on proven waste excavation and handling technology. The off-site disposal alternative would involve a relatively limited design effort and could be initiated quickly. The duration of the actual removal effort is proportional to the amount of waste removed. The large quantity of waste materials to be removed and the reconstruction of settling basins would require at least three construction seasons.

Removal of waste from the site limits future liabilities and has a relatively small risk of failure (i.e., not meeting program objectives).

Some of the site would be released for other uses and long-term environmental impacts are minimal. The off-site disposal alternative may not be favored by the local populace due to increased waste handling and transportation involved.

During the removal effort, potential environmental impacts would be related to "normal" construction-generated pollution (e.g., noise, dust) and the release of hazardous pollutants from both routine and accident conditions. Potential for exposure to dust and airborne asbestos fibers would be maximum for off-site landfilling due to increased waste handling and transportation involved. A properly managed and executed operation could limit such impacts to acceptable levels.

The capital cost associated with waste/soil removal and disposal is approximately linear. On a very preliminary basis the cost of excavating, transporting, and disposing bulk waste/soil is estimated to be about $27.0 to $30.0 per cubic yard. In addition, clean soil and liner material would be required to reestablish process water settling basins and restoring site to normal grades. Total cost of this alternative would be the highest of all of the evaluated technology alternatives for mitigating the potential impacts of the contaminated wastes/soil at this site.

3.3 DEVELOP REMEDIAL ACTION ALTERNATIVES

In section 3.2 alternative technologies were evaluated using environmental, public health, technical and cost factors. Each technology was rated on each factor using a numerical score. This evaluation has indicated that, for the objectives to be achieved at this site, on-site stabilization technology is not a proven technology, involves high risks and is less likely to be accepted by public due to increased potential of higher levels of airborne contaminants and noise. The screening of technologies has indicated that stabilization technology is the least favorable for this site and soil covering with vegetation is the most favorable technology for this site (see Table 3-1). Therefore, the on-site stabilization technology is being excluded from further considerations for this site.
The following range of remedial action alternatives are available based on the screened technologies.

- No action
- Grading and seeding
- Soil covering with vegetation

- Soil covering without vegetation
- Capping
- On-site landfilling
- Off-site landfilling

A general discussion of the conceptual design, technical, environmental, public health and cost factors involved in each of soil covering (a minimum of 18" cover) and vegetation, soil covering (24" cover) without vegetation, capping, on-site landfilling and off-site landfilling alternatives is presented in Section 3.2. The remaining two alternatives are discussed below:

<u>No Action</u>

This alternative would involve leaving the wastes on the disposal area in their current state. Under this alternative some of the lead and asbestos containing waste materials/soil would remain exposed. The groundwater and surface water would however be sampled bi-annually and analyzed for lead and other organic and inorganic water quality parameters to evaluate future migration potential of lead to groundwater.

The potential of human and wildlife exposure to on-site asbestos fibers and lead would continue to exist. The site would therefore not meet remedial response objectives and requirements of Section 105 of The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). There may also be public opposition to this alternative. In the short-term, there would be considerable savings in the commitment of natural resources, energy and money. However, in the long-term the environment and public health may be adversely impacted.

<u>Grading and Seeding</u>

This alternative would involve grading of waste materials/soil and laying a 3" thick layer of top soil on all surfaces except the roadways, and top of dikes. All surfaces covered with the top soil would be fertilized and seeded. In addition, a minimum cover of 24" clean soil on top of dikes, 4" to 8" thick gravel on all-weather dike roadways and nominal 12" thick riprap on 4" bedding material on interior slopes of settling basins would be provided. The groundwater and surface water would be sampled annually and analyzed for lead and other organic and inorganic water quality parameters.

This alternative would be expected to diminish the potential for on-site airborne asbestos emissions and direct contact with waste materials/soil containing high levels of lead but provide poor groundwater protection. However, 3" top soil cover will not meet the NESHAP regulation for asbestos disposal sites (40 CFR Part 61.153). A limited potential of human and wildlife exposure to asbestos fibers and lead may continue to exist. The site may therefore not fully meet the remedial response objectives and the requirements of CERCLA. There may also be public opposition to this alternative. In the short-term, there would be reduced commitment of energy, money and natural resources due to reduced use of materials as opposed to soil covering or capping alternatives. However, in the long-term the environment and public health may be adversely impacted.

3.4 SCREENING OF ALTERNATIVES

A two step procedure is used for screening the available alternatives. Each alternative is evaluated first on the basis of its environmental and public health impacts. Those which do not adequately protect the environment and public health are eliminated. Those providing similar environmental and public health and welfare benefits are subjected to cost screening.

3.4.1. ENVIRONMENTAL AND PUBLIC HEALTH SCREENING

No Action: Under no action alternative some of the waste materials/soil, containing lead and asbestos would remain exposed. Both lead and asbestos fibers can be carcinogenic to human and wildlife population. However, there is no current evidence to suggest that the inorganic lead found at this site is a human or animal carcinogen. The potential of exposure of Manville employees, working on the site and wildlife harboring in the vicinity of the site, to lead and airborne asbestos fibers would remain. In the short-term, there would be considerable savings in the commitment of energy and other resources.

Groundwater and surface water in the vicinity of the site do not appear to be contaminated by lead and asbestos and are not estimated to be impacted because of the characteristics of the waste materials disposed on this site. The no action alternative, although it does not adequately protect the environment or public health and welfare, will be used for comparison in subsequent detailed analysis of alternatives to satisfy requirments of NCP.

Grading and Seeding:

Potential for on-site airborne asbestos emissions and direct contact with lead-containing waste materials would decrease but may not be eliminated. A limited threat of human and wildlife exposure to asbestos fibers and lead may continue to exist. The site may therefore not fully meet the remedial response objectives.

Also adverse short-term impact may occur due to increased level of airborne asbestos during construction activities. This adverse impact can be minimized by using extensive program of wetting material, personal monitoring for asbestos, use of warning signs and appropriate protective health and safety equipment during construction.

Soil Covering with and Without Vegetation or Capping

Each of these three alternatives would provide adequate protection to human and wildlife population in the vicinity of the site.. Capping would provide added protection to groundwater (which, however, is not of primary concern at this site). The geological setting of this site is such that the majority of the infiltration water along with the settling basin seepage is intercepted and recycled through the service water lagoon and the industrial canal. Lead and asbestos contaminants in the waste materials are in the encapsulated and non-leachable forms. In view of these observations, the added benefit of capping (of reduced potential groundwater contamination) would not off-set its greater short-term adverse environmental impacts due to increased material handling.

Each of the three alternatives involves grading and handling of asbestos and lead containing waste materials. In the short-range, this may increase level of airborne asbestos fibers in the vicinity of the construction area. This may have adverse impact on the public health and welfare on a temporary basis. An extensive program of wetting these materials, personal monitoring, use of warning signs and appropriate protective health and safety equipment during construction would be required to minimize these short-range adverse public health impacts and limit such impacts to acceptable levels.

On-site Landfilling

In the long-term this alternative would provide adequate protection to human health and environment in the vicinity of the site.. It would also protect groundwater and surface water from potential contamination (which is not of concern at this site). Because of the longest implementation time of this alternative, there would be the greatest exposure of public and wildlife to lead, airborne asbestos, dust and noise. A properly designed and implemented program involving wetting of waste materials, personal monitoring, use of warning signs and protective health and safety equipment during construction would be required to minimize the short-term adverse public health impacts. As compared to off-site landfilling, the transportation of wastes would be greatly reduced, thereby decreasing risks associated with material transportation accidents. Land use would be restricted in the on-site landfill area but more land would be available along the Lake Michigan shore because of the removal of deposited waste materials.

Off-Site Landfilling

The short-term and long-term health and environmental impacts of this alternative would be similar to that of on-site landfilling except that the off-site landfilling alternative would involve somewhat shorter period of construction generated pollution (e.g. noise, dust) and greater risk of transportation accidents. A properly managed and executed waste removal and hauling operations could limit short-term adverse impacts to acceptable levels.

3.4.2 COST SCREENING

Except no action alternative, all the alternatives would diminish the potential for on-site airborne asbestos emissions and direct contact with lead containing waste materials/soil. Grading and seeding alternative may not fully protect the environment and public health in the vicinity of the site.

Soil covering with and without vegetation and capping alternatives provide more or less similar environmental, public health and welfare benefits for this site. Also, on-site landfilling and off-site landfilling alternatives more or less provide similar public health and environmental benefits.

The estimated capital and operation and maintenance costs of each of the alternatives are presented in Appendix A. These costs have been estimated using vendor estimates and estimates for similar recent projects. Present worth analysis of costs has been made using a discount rate of 10% and a performance period of 30 years. A summary of cost analysis of different alternatives is presented in Table 3-2. Although the public health and environmental benefits of soil covering with vegetation, soil covering without vegetation and capping are more or less similar, their present worth costs are $4,086,090; $4,134,040 and $7,590,140 respectively. Therefore out of these three alternatives, only the least cost alternative of soil covering with vegetation will be used for detailed analysis. The on-site and off-site landfilling alternatives, although the two most costly alternatives, will be evaluated further because of the NCP requirements.

Thus the alternatives remaining after the two stage screening process are as follows:

- No action
- Grading and seeding
- Soil covering with vegetation
- Off-site landfilling
- On-site landfilling

TABLE 3-2 SUMMARY OF COST ANALYSIS

ALTERNATIVE	COST ESTIMATES ($1,000) Capital	Annual O & M	Present Worth at 10% Discount Rate for 30 years
No action	15	33	326
Grading and Seeding	2,615	54	3,124
Soil Covering with Vegetation	3,624	49	4,086
Soil Covering without Vegetation	3,795	36	4,134
Capping	7,128	49	7,590
On-Site Landfilling	38,555	80	39,309
Off-Site Landfilling	70,565	300	73,393

4.0 REMEDIAL ACTION ALTERNATIVES

This chapter provides a detailed description of each of the alternatives which were identified as viable after initial screening. Based on initial screening, the soil covering with vegetation alternative is viewed as most appropriate for remedial action (for securing the waste materials/soil) on this site.

Four alternatives have been devised for mitigating potential adverse impacts of the contaminated materials/soil at this site. A fifth no action alternative has been added to fulfill NCP requirements. These alternatives are summarized as follows:

- Alternative I: No Action

  Involves leaving the waste materials/soil on the disposal area in their current state, but includes monitoring of groundwater and surface water.

- Alternative II: Grading and Seeding

  Involves grading of waste materials/soil, adding top soil, fertilizing and seeding.

- Alternative III: Soil Covering with Vegetation

  Involves grading of waste materials/soil and laying a minimum of 18" compacted clean soil cover, adding top soil, fertilizing and seeding.

- Alternative IV: Off-Site Landfilling

  Involves excavation, removal, transportation and disposal of waste materials/soil in an approved off-site landfill.

- Alternative V: On-Site Landfilling

  Involves excavation, removal, transportation and disposal of waste materials/soil in an on-site landfill designed and constructed specifically for the disposal of Johns-Manville waste materials/soil.

Each of these alternatives is discussed in detail in the following sections.

4.1 NO ACTION ALTERNATIVE

This alternative involves leaving the wastes on the disposal area in their current state and continuation of the present waste treatment and disposal activities. Obviously this alternative would not provide control of the potential source of contamination at this site, and potential of exposure of public and wildlife to the lead and asbestos containing wastes would remain. The groundwater and surface water would however be monitored bi-annually to detect whether water quality is degraded in future.

4.1.1 SCOPE OF WORK

Activity to be accomplished under this alternative would consist of the following:

- Monitoring and reporting of groundwater and surface water quality.

Description of this activity is presented in the following paragraph.

4.1.1.1 MONITORING AND REPORTING OF GROUNDWATER AND SURFACE WATER QUALITY

The surface water and groundwater would be sampled bi-annually and analyzed for lead and other organic and inorganic water quality parameters (such as pH, SO_4, No_3-N, Cr, Al, Cl, specific conductance, total alkalinity pentachlorophenol and volatile organic compounds indicated by USEPA Scans 601 and 602). A contingency plan will be developed to take necessary remedial action in the event that contaminant concentrations which would pose a threat to human health and environment are detected. The duration of monitoring and reporting of the results to USEPA would be of the order of 30 years unless indicated otherwise by prolonged monitoring. A minimum of eight (8) monitoring wells (3 north of the site, 3 east of eastern site boundry, two of which will be two well clusters, one west and one south of the site) and three (3) surface water sampling locations (treatment basins influent, effluent and industrial canal) as shown in Figure 2-5 would be monitored.

4.2 GRADING AND SEEDING ALTERNATIVE

This alternative involves grading of waste materials/soil and establishing vegetation. The three active waste disposal areas would continue to be used for current and future waste disposal. Written waste handling procedures would be provided to the staff working at the site for asbestos disposal pit, the miscellaneous disposal pit, and the sludge disposal pit. However, the asbestos disposal pit would be closed and provided with the same cover thickness as the remaining dry disposal areas in 1989 and any asbestos containing material generated after closure would be disposed off-site in an approved landfill.

4.2.1 SCOPE OF WORK

Activities to be accomplished under this alternative would consist of the following:

- Site preparation and set-up
- Clearing and grubbing and miscellaneous site work
- Grading wastes
- Placing riprap on settling-basin slopes and gravel on dike roadways
- Placing top-soil and constructing site drainage ditches
- Re-vegetation with grasses and shrubs
- Support services
- Monitoring and reporting of surface water and groundwater quality

Site preparation and set-up activities, support services and monitoring of surface water and groundwater in the vicinity of the site would also be applicable, to a varying degree, to the grading and seeding, soil covering, on-site landfilling and off-site landfilling alternatives. Descriptions of the actions that would be taken during each of the identified activities are presented in the following paragraphs.

4.2.1.1 SITE PREPARATION AND SET-UP

Prior to implementing waste handling operations, the site would be prepared for the work. Site preparation would be needed to achieve the following objectives:

- Provide a safe work site for personnel both inside and outside the site boundaries.
- Provide environmental controls so that contamination is not spread while accomplishing the remedial action program.
- Provide facilities so that production and schedule objectives can be met for the range of uncertainty for the waste material to be removed.

Site preparation activities would include construction of a temporary fence with vehicular access gates, establishing site work zones, and location of support facilities at the sites (e.g., office trailers, decontamination facilities for material handling equipment, decontamination and health and safety monitoring trailers).

4.2.1.2 CLEARING AND GRUBBING AND MISCELLANEOUS SITE WORK

This would involve cutting of volunteer and other trees and shrubs growing on the dike slopes and top of waste piles and removal of stumps to facilitate site grading. Tree cuttings and stumps would be buried on site in the miscellaneous waste disposal pit and/or in the collection basin or burned on site.

The miscellaneous work would involve the following:

- Clean up of the beach and the southwest portion of the waste disposal area.
- Fence (where feasible) on the eastern site boundry along the elevated area near the beach.
- Dikes at the depressed areas along the north side of the industrial canal.
- Additional warning signs along the waste disposal area boundry fences to comply with the requirements of NESHAP. These signs may be removed after the site has been remediated and asbestos disposal pit has been closed.

4.2.1.3 GRADING WASTES

This would involve site grading by using existing waste materials/soil on the site and clean fill borrowed from off-site locations. All dikes would have a maximum slope of 1:2 (one vertical: two horizontal). All dike roadways would be about 20 feet wide. All top surfaces would slope towards settling basins or to peripheral ditches. It is estimated that grading would involve about 30,000 cubic yards of balanced cut and fill and 21,000 cubic yards of borrow-fill.

4.2.1.4 PLACING TOP SOIL AND DRAINAGE DITCHES

The graded waste materials would be covered with a minimum of 3" of top soil. Top soil would be spread on all surfaces except the roadways and top of dikes.

All surface runoff from the site would flow to process water treatment basins or to the peripheral ditches. About 11,000 linear feet of shallow grassed peripheral ditches would be used to collect and direct all runoff from this site to the industrial canal. In addition, the existing northeast ditch and southeast ditch (at the northeast corner of the miscellaneous disposal pit) would be replaced by buried drainage pipes, filled and closed and dike seepage would be collected through the drainage pipes. The northeast corner of the miscellaneous disposal pit which is presently open, will be elevated such that no surface runoff from the pit would exit from this area.

4.2.1.5 REVEGETATION WITH GRASS AND SHRUBS

All surfaces covered with top soil would be fertilized and seeded using hydromulch. The hydromulch would consist of fertilizer and germinated seeds of fast growing grasses (fescue, timothy, reed canary and bluegrass). In addition, a limited number of ornamental trees/shrubs would be planted along the periphery of the site. This vegetation would increase evapotranspiration, reduce erosion, increase stability of slopes, improve site appearance and reduce potential direct contact and airborne dispersion exposure pathways.

4.2.1.6 PLACING RIPRAP ON SETTLING-BASIN SLOPES AND GRAVEL

One layer of nominal 12" thick lime stone riprap would be placed (by drop method of placement) on portions of interior slopes of settling basins where it is feasible to place riprap. Suitable bedding material (4" thick) will be used to prevent erosion of soil underneath the riprap. All other exposed interior slopes of settling basins would be covered with top soil and fertilized and seeded.

A minimum of 24" clean soil cover will be placed on top of dikes and dike roadways. In addition, heavily used dike roadways will be covered with 8" of compacted gravel, and lightly traveled dike roadways with 4" compacted gravel, to permit their use during all seasons.

A contingency plan will be implemented to ensure that no asbestos-containing sludge is dredged in the future and disposed on-site. This contingency plan will include the discontinuance of dredging activities in the 33-acre settling basin. If any sludge is removed from the 33-acre settling basin in the future, it will be tested for asbestos using USEPA approved methods and disposed of in accordance with applicable regulations.

4.2.1.7 SUPPORT SERVICES

During the construction work, support services would include security, worker health and safety protection, and environmental monitoring. Site security would be enhanced by the location of a temporary fence with vehicular access gates and signs. A security guard at the site is not needed as the entrance to the plant is monitored by a security guard. These security measures would greatly diminish the possibility of unauthorized personnel entering the site. During active construction times, the site might be viewed as an attractive nuisance from dust and noise and would be protected accordingly. Active construction areas would be wetted prior to grading and handling of dry waste materials. All soil/bulk materials brought to the site for construction would be tested for contamination. One composite sample would be analyzed out of every 2,000 to 4,000 cubic yards of soil/bulk materials hauled to the site. Specific criteria for accepting or rejecting the soil hauled to the site for use as a cover material will be developed using the background levels of inorganic lead and/or asbestos found in the off-site soil samples. Trucks coming to the site for delivering soil and other materials would be spray washed (on out-side) on a decontamination pad prior to leaving the site and the washwater would be drained to settling basins or peripheral ditches for treatment and plant reuse.

A worker health and safety program would be employed throughout active construction. At this time, it appears that Level C protection would be appropriate for waste handling and grading activities and level D protection for other activities. Level C protection includes use of respirators (approved by NIOSH or Bureau of Mines, Dept of Interior) coveralls, gloves, foot covering, head covering and Level D protection includes all of above except use of respirators.

Environmental monitoring would be required to assess airborne releases of contaminants during the waste handling and grading operation. This would consist of the use of personal samplers, using 0.8 micrometer porosity filter, in the breathing zone of workers on the site. Exposure of any worker would not exceed 8-hr weighted average airborne asbestos concentration of 0.2 fibers/cubic centimeter and a ceiling concentration of 10 fibers/cubic centimeter for fibers longer than 5 micrometers.

4.2.1.8 MONITORING AND REPORTING OF SURFACE WATER AND GROUNDWATER QUALITY

This would be the same as described in Section 4.1.1.1 for the no action alternative except the frequency of sampling would be once per year. The frequency has been reduced because of the expected reduction in infiltration flows and hence potential contaminant migration from the disposal area, due to 3" top soil and vegetation. The duration of monitoring and reporting of the results to USEPA would be of the order of 30 years unless indicated otherwise by prolonged monitoring.

4.3 SOIL COVERING WITH VEGETATION

This alternative involves grading of waste materials/soil, covering with a minimum of 18" compacted non-asbestos-containing soil and growing and maintaining a cover of vegetation on the inactive disposal area. Two variations of this alternative are also discussed under this remedial action alternative. These differ from the primary alternative only in the thickness of the compacted non-asbestos-containing soil cover. One variation includes a minimum of 24" cover and the second a minimum of 30" cover. The three active waste disposal areas (sludge disposal pit, asbestos disposal pit and miscellaneous disposal pit) would continue to be used for current and future waste disposal. Written waste handling procedures would be provided to the staff working at the site for asbestos disposal pit , the miscellaneous disposal pit, and the sludge disposal pit. However, the asbestos disposal pit would be closed in 1989 and any asbestos-containing material generated after closure would be disposed off-site in an approved landfill.

4.3.1 SCOPE OF WORK

Activities to be accomplished under this alternative would consist of the following:

- Site preparation and set-up
- Clearing and grubbing and miscellaneous site work
- Grading wastes
- Soil covering and compacting
- Placing riprap on settling-basins slopes and gravel on dike roadways
- Placing top-soil and constructing drainage ditches
- Revegetation with grasses and shrubs
- Support Services
- Monitoring and reporting of surface water and groundwater quality

Descriptions of the actions to be taken during each of the above identified activities except soil covering and compacting are presented in Sections 4.2.1.1 through 4.2.1.8. Description of actions to be taken under soil covering and compacting are presented in the following paragraph

4.3.1.1 SOIL COVERING AND COMPACTING

The graded materials/soil would be covered with a minimum of 15" or 21" or 27" of compacted non-asbestos-containing soil depending upon the variation selected. Areas on the southwest and northeast corners of the site would also be provided with soil cover. A top soil cover of 3" placed over the soil cover would provide added cover thickness and suitable soil for quick growth of grasses.

4.4 OFF-SITE LANDFILLING ALTERNATIVE

This alternative calls for the removal and off-site disposal of the entire waste materials/soil at this site. The materials to be removed would be the materials in the waste piles, sludge pit and other disposal pits plus all of the materials in the dikes of the process water treatment basins and the wet sludge in these basins (Figure 2-5). These wastes are classified as special wastes but not as hazardous wastes. All waste would be excavated, loaded and transported to permitted landfilling facilities for final disposition. The process water treatment-basins would be rebuilt and monitoring of local groundwater and surface water would continue to assure that all contributory sources from the site had been removed and that the ground- and surface water would not be degraded in the future. In future, all waste materials/soil generated at the Waukegan facilities would be disposed in approved off-site landfills.

4.4.1 SCOPE OF WORK

Activities to be accomplished under this alternative would consist of the following:

- Site preparation and setup
- Waste removal and handling
- Rebuilding of process water treatment basins and site grading
- Support services
- Monitoring and reporting of groundwater and surface water quality

Description of the actions to be taken during site preparation and set-up activities and ongoing support services are the same as discussed in Sections 4.2.1.1 and 4.2.1.7 for the grading and seeding alternative. Descriptions of actions to be taken during each of the remaining activities are presented in the following paragraphs.

4.4.1.1 WASTE REMOVAL AND HANDLING

Waste removal operations would begin with the waste materials/soil in the waste piles and disposal pits. Currently generated waste materials/soil would not be brought to the site and would be transported directly to approved off-site landfills. Process water would continue to be treated at the site and wet sludge would be dewatered at site and hauled to an approved off-site disposal facility.

About 20,000 cubic yards of waste materials and 800 cubic yards of sludge would be disposed in the off-site landfill annually.

Excavation would proceed downward until all visible waste materials/soil were removed and natural beach sand was visible. Additional 4" to 6" natural sands would be removed, stock piled and tested for asbestos and lead contamination. If the bulk asbestos level were less than one percent and the lead level less than 40 mg/kg, then this soil would be considered non-contaminated and used for construction of dikes of the process water treatment basins.

Removal of waste materials from dikes of treatment basins would require concurrent construction of treatment basins on land available after removal of waste materials from waste piles and disposal pits.

Waste would be loaded and transported from the site in the bulk solid containers (i.e., sealed dump trailers, roll-offs) for specific waste materials, sludge and friable asbestos wastes.

Before leaving the site, all vehicles would be inspected and decontaminated as necessary and all waste transportation manifests would be completed.

An estimated 2.2 million cubic yards of waste materials/soil would have to be removed for off-site disposal. These would contain about 25,000 cubic yards of friable asbestos wastes, 50,000 cubic yards of wet sludge and 125,000 cubic yards of dry sludge.

Commercial landfills are available (BFI and ARF landfills) in Lake County. These are approved to receive materials from the Johns-Manville Waukegan site. Available capacity in the existing landfills in Lake County to receive Johns-Manville waste manterials/soil however is limited. Other alternative facilities might be located throughout the Midwest to receive the materials from this site, if required.

4.4.1.2 REBUILDING OF PROCESS WATER TREATMENT BASINS AND SITE GRADING

Approximately 57 acres of settling basins and related transfer structures, access roads and toe drains would be constructed concurrent with waste removal activities. The three process water streams would be combined and pumped to approximately 6 acres of sludge settling basins with 12' side water depth (SWD). The effluent from these basins would flow through another 6 acres of settling basins with 8' SWD. These would be followed by 35 acres of settling basins (12' SWD) and 10 acres of polishing basins (8' SWD). The effluent from the polishing basins would flow to the existing industrial canal for recycling. All interior slopes of dikes and basin bottom surfaces would be lined with two feet thick clay (laid and compacted in layers of 6" to 8"). Berms and access roads would have 8" gravel and remaining exposed surfaces would be covered with topsoil, fertilized and seeded. The site would be filled with clean fill and graded, and surface drains would be provided for run off collection and discharge to industrial canal.

The sludge periodically removed from the sludge settling basins would be dewatered by using a 2 acre unlined sludge drying basin. This dewatering method was chosen as this has been successfully used at this site for many decades. The dried sludge (estimated about 800 cubic yards per year) would be periodically removed for off-site disposal in an approved landfill.

4.4.1.3 MONITORING AND REPORTING OF SURFACE WATER AND GROUNDWATER QUALITY

Because of the continued use of clay-lined process water treatment basins, the surface water and groundwater would be sampled (at locations such as outlined in Section 4.1.1.1) annually and analyzed for lead and other organic and inorganic water quality parameters. The duration of monitoring and reporting of the results to USEPA would be of the order of 30 years unless indicated otherwise by prolonged monitoring.

4.5 ON SITE LANDFILLING ALTERNATIVE

This alternative involves removal and disposal of the entire waste materials/soil to an on-site landfill designed and constructed specifically for the disposal of Johns-Manville Waukegan waste materials. The materials to be removed would include all materials in the waste piles, waste disposal pits, settling basin dikes and the wet sludge in the settling basins. A landfill would be constructed on the northwest corner of the Manville plant property. All wastes would be excavated and transported to this landfill for disposal, and this portion of the landfill would be closed. A portion of this landfill would be kept active for the disposal of all current and future waste materials from the Manville facilities.

The process water treatment basins would be rebuilt and monitoring of local groundwater and surface water would continue to assure that all contributory sources from the site had been removed and that the groundwater and surface water quality is not degraded in the future by the process water treatment basins and the on-site landfill.

4.5.1 SCOPE OF WORK

Activities to be accomplished under this alternative consist of the following:

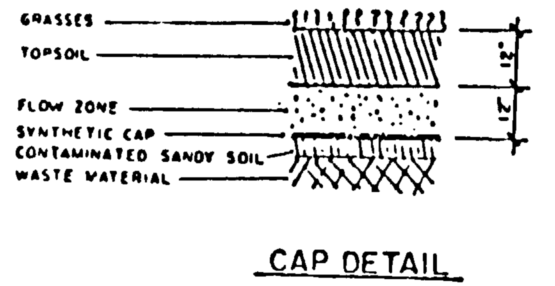
- Site preparation and setup
- Developing on-site landfill area
- Installing multi-layer liner
- Waste removal and handling
- Collection and treatment of leachate and runoff
- Placing multi-layered cap for closure
- Rebuilding of process water treatment basins and site grading
- Support activities
- Monitoring and reporting of surface water and groundwater quality

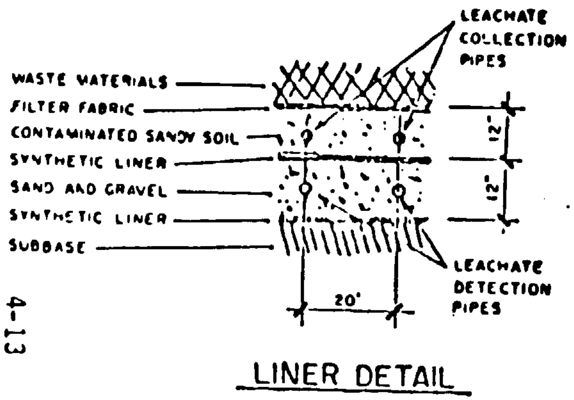
Descriptions of actions to be taken during site preparation and setup, waste removal and handling, and rebuilding of process water treatment basins and site grading and support activities are the same as in sections 4.2.1.1, 4.4.1.1, 4.4.1.2 and 4.2.1.7 respectively. Descriptions of actions to be taken during each of the remaining activities are presented in the following paragraphs.

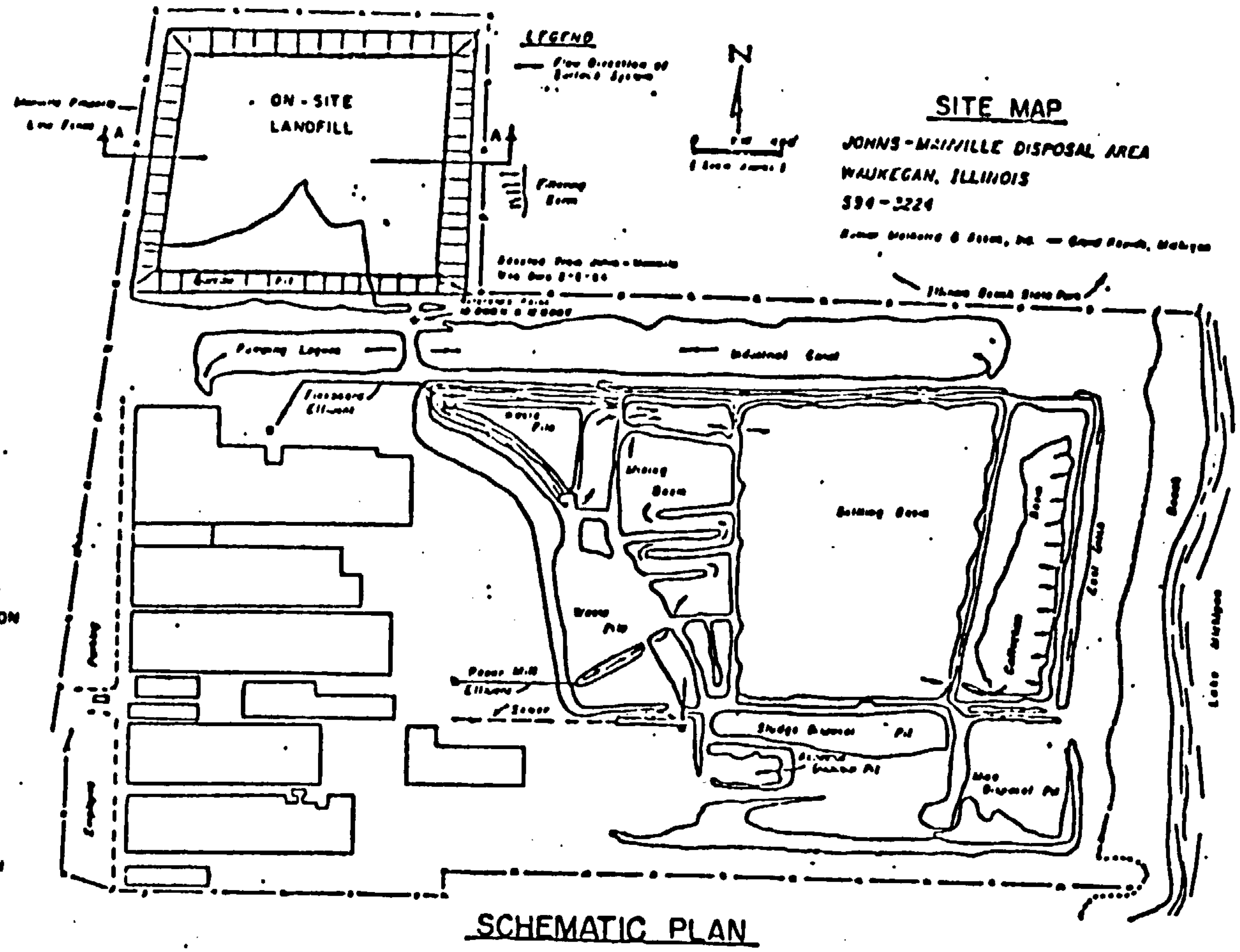
Figure 4-1 shows a plan view, section and liner and cap details.

4.5.1.1 DEVELOPING ON-SITE LANDFILL AREA

About 46 acres in the northwest corner of the Johns-Manville plant property would be cleared and grubbed of all shrubs and







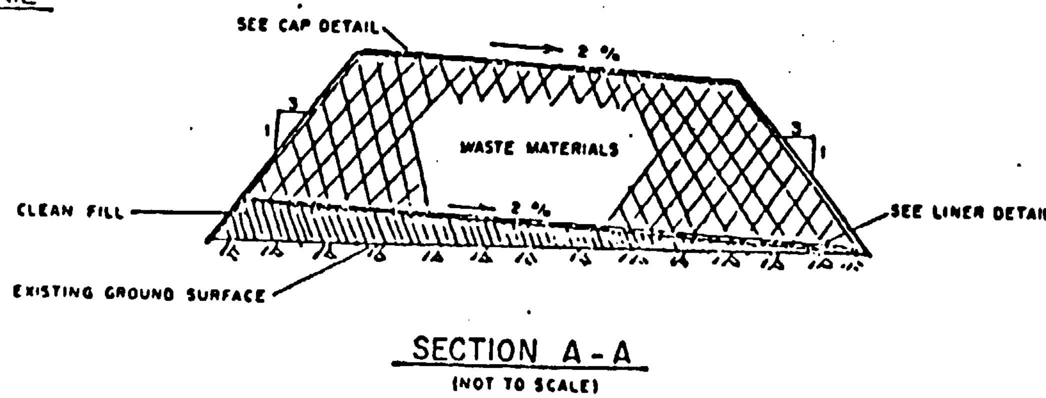


FIGURE 4-1
SCHEMATIC PLAN
SECTION, CAP AND LINER DETAILS
FOR
ON - SITE LANDFILL

trees. The tree cuttings and stumps would be transported off-site for disposal. Low areas would be filled with clean soil and the site graded and compacted as a part of subbase preparation for an above ground landfill.

4.5.1.2 INSTALLING MULTI-LAYER LINER

A dual liner system, would be used to minimize off-site contaminant migration and to provide a degree of long-term isolation similar to that available from commercial landfills. The use of dual liner system would be warranted due to the presence of permeable surficial soils over a shallow aquifer at this site.

The liner would consist of dual synthetic membranes, each 30 mils thick PVC, sandwiching a leachate detection system. The leachate detection system would be constructed by placing perforated four-inch-diameter polyvinyl chloride (PVC) pipes at 20-foot intervals within a 12-inch blanket of sand and gravel. The sand would be taken from the landfill construction site and blended in proper proportions with gravel to achieve a permeability of 1×10^{-2} centimeters per second.. The leachate detection system would drain to leachate detection manholes.

4.5.1.3 COLLECTION AND TREATMENT OF LEACHATE AND RUNOFF

Perforated four-inch-diameter PVC pipes at 20-foot intervals would be placed atop the upper synthetic liner to collect any leachate generated. These pipes would be placed within contaminated sandy soils removed from the disposal area. The contaminated soil is sufficiently permeable that a sand and gravel layer would not be needed for leachate collection.

The leachate collection system would drain to separate leachate removal manholes. Filter fabric would be placed atop the leachate collection blanket.

Surface runoff from the landfill would be collected by properly sloping all surfaces to peripheral ditches. These ditches would discharge the collected runoff to the process water treatment and recycling basins.

The collected leachate would be analyzed for asbestos, lead and other contaminants and treated for disposal in the treatment basins or off-site, as appropriate.

4.5.1.4 PLACING MULTI-LAYERED CAP FOR CLOSURE

When the contaminated waste materials/soil placement reached the designed level, a layer of contaminated or clean soil would be placed over the waste materials and graded to obtain a relatively smooth surface. A 30 mils thick PVC membrane would be placed over the smoothed surface. This membrane would be covered with one-foot layer of sand free of sharp objects (taken from the Manville property or an off-site location) to serve as the infiltration flow zone. A 12" thick blanket of top soil would be placed over the flow zone and fertilized and seeded with quick growing grasses using hydromulch.

4.5.1.5 MONITORING AND REPORTING OF SURFACE WATER AND GROUNDWATER QUALITY

Groundwater and surface water would be sampled using newly installed monitoring wells around the on-site landfill and the monitoring wells and surface water sampling locations such as outlined in Section 4.1.1.1. The later monitoring locations would be added because of the continued use of the clay-lined process water treatment basins. Samples would be collected annually and analyzed for lead and other organic and inorganic water quality parameters. The duration of monitoring and reporting of the results to USEPA would be of the order of 30 years unless indicated otherwise by prolonged monitoring.

5.0 ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

This chapter provides a detailed analysis of the remedial action alternatives. Each alternative has been evaluated for technical feasibility, institutional requirements, public health and environmental impacts, capital costs and operation and maintenance costs. It must be noted that the primary objective of a remedial action alternative at this site is to secure the contaminant source or mitigate potential direct contact and airborne dispersion exposure pathways.

Analysis of alternatives is presented in detail in the following sections.

5.1 TECHNICAL FEASIBILITY

Technical feasibility of an alternative involves its evaluation based on the following factors:

- Performance
- Reliability
- Implementability
- Safety (during implementation)

Evaluation of different alternatives based on each of these factors is presented in the following paragraphs

5.1.1 PERFORMANCE

Performance of an alternative is a measure of its effectiveness and the length of time for which this level of effectiveness can be maintained.

Effectiveness of an alternative can be measured in terms of the level of cleanup it provides relative to the relevant and applicable contaminant removal standards and guidelines, or how well it achieves the objectives of the remedial action.

Four evaluation factors were used to assess relative performance of alternatives. These are:

- Proven technology
- Degree of groundwater protection
- Elimination of direct contact and airborne dispersion pathways
- Useful life (time for which level of cleanup can be maintained)

No action alternative obviously does not provide any level of contaminant removal or protection from direct contact with the contaminants and exposure to the airborne asbestos fibers. Similarly off-site landfilling alternative provides the best level of site cleanup because the contaminants are removed from the site for ever. However, groundwater contamination is not expected because the contaminants at this site are not in a readily leachable form. The on-site landfilling alternative is considered not as effective as the off-site landfilling alternative because of the potential failure of the multi-layer liner in the long-range. However, the on-site landfilling alternative is considered more effective than the grading and seeding and soil covering with vegetation alternatives because of its added benefit in terms of groundwater protection. Grading and seeding alternative is expected to minimize potential direct contact and exposure to airborne asbestos but does not meet the NESHAP regulations of 6" soil cover with vegetation and does not provide groundwater protection. It also has relatively lower useful life.

Soil covering with vegetation alternative or its variation is expected to eliminate potential direct contact and exposure to airborne asbestos, and thus achieve the primary abjective of the remedial action. It also provides some groundwater protection.

Technologies involved in the off-site and on-site landfilling and soil covering with vegetation alternatives are considered relatively proven and readily available technologies based on the current knowledge and standards. Considering the long-term performance of these technologies in meeting the objectives of the remedial action at this site, the remedial action alternatives are rated in the following decreasing preference order:

- Off-site landfilling
- On-site landfilling
- Soil covering with vegetation
- Grading and seeding
- No action

5.1.2 RELIABILITY

Reliability of an alternative depends upon the following factors:

- Operation and maintenance requirement

- Risk of failure or demonstrated performance

Operation and maintenance requirements are the least for the no action alternative. Operation and maintenance requirements of off-site landfilling alternative are second best of all the alternatives as the operation and maintenance of the off-site landfill is not Manville responsibility.However, Manville would continue to be responsible for operating and maintaining the process water treatment system and monitoring of surface water and groundwater quality in the vicinity of the site. All manufacturing waste materials and dewatered sludge from process water treatment would be removed for off-site disposal through licensed waste haulers. Operation and maintenance requirements of the on-site landfilling alternative are expected to be more than that of grading and seeding and soil covering with vegetation alternatives. This is due to operating and maintenance activities and monitoring of groundwater at two locations (on-site landfill and process water treatment basins) as well as required dewatering and disposal of process water sludge and treatment of leachate.

Risk of failure is the least for the off-site landfilling alternative as the wastes are removed from the site. On-site landfilling alternative provides the second best alternative from the demonstrated performance point of view. This would be due to securing of the contaminated waste materials in the on-site landfill by using multi-layer liner and cap. No action alternative obviously is the least desirable as it does not provide any mitigation of the potential direct contact and airborne dispersion pathways. Soil covering with vegetation alternative or its variation is estimated to have less risk of failure than grading and seeding because of the added compacted soil cover provided over the contaminated waste materials.

5.1.3 IMPLEMENTABILITY

Implementability of an alternative is the relative ease of its installation and the time it requires to achieve the desired level of remedial response. It depends upon the following factors:

- Constructability

- Time required to implement and achieve beneficial results

Off-site landfills as well as material and equipment needed to implement soil covering with vegetation, grading and seeding, off-site landfilling and on-site landfilling alternatives are available. However, the on-site landfill construction would require zoning clearances and applicable local, State and federal permits. Reconstruction of process water treatment system would require concurrent removal of waste materials and construction and operation of process water treatment basins. Because of these considerations, the grading and seeding or soil covering with vegetation alternatives are considered to be more favorable (from the constructability point of view) than the on-site or off-site landfilling alternatives.

Time required to implement and achieve beneficial results includes time required for design and approvals, construction and start-up time. Beneficial results of any alternative would be realized as soon as it is constructed as only source control remedial actions are being targeted. No action alternative does not require any new construction and is not likely to show any beneficial remedial results. Grading and seeding and soil covering with vegetation alternatives are estimated to be fully implemented in two construction seasons (1987 and 1988). Because of the large quantities (2.2 million cubic yards) of waste materials to be removed and reconstruction of process water treatment system, the off-site alternative is estimated to be completely implemented in three construction seasons (1987, 1988 and 1989). On-site landfilling alternative involves additional time for permits, design and approval, and construction of the landfill, and therefore, is estimated to be implemented in four construction seasons (1987, 1988, 1989 and 1990).

5.1.4 SAFETY

This evaluation involves short-term and long-term threats to the safety of human population and environment during implementation of an alternative. Because of the inert and noncombustible nature of the waste materials, the fire and explosion risks at this site are minimal. However, exposure to airborne asbestos fibers resulting from on-site construction activities is a potential risk at this site.

Because of the longer implementation time and handling of large volumes of asbestos contaminated waste materials, the on-site and off-site landfilling alternatives have greater potential for exposure of public and wildlife to lead, airborne asbestos, dust and noise than other alternatives. However, as compared to the off-site landfilling alternative, the transportation distance in the on-site landfilling alternative is greatly reduced, thereby decreasing risks associated with material transportation accidents. Grading and seeding and soil covering with vegetation alternatives also have potential for exposure of public and wildlife to lead, airborne asbestos, dust and noise. However, because of reduced time of implementation and reduced level of material handling, the potential risk is significantly less than off-site or on-site landfilling alternatives. A properly managed and executed waste handling, removal and hauling operations would limit the short-term threats of exposure to lead, airborne asbestos, dust and noise.

In the no action alternative, the potential of short-term human and wildlife exposure to on-site asbestos fibers and lead is the least because of absence of construction activities. In the long-term, all alternatives, except no action alternative, are expected to eliminate or reduce potential threat of human and wildlife exposure to lead and on-site airborne asbestos fibers. However, the grading and seeding alternative may not adequately eliminate potential threat of exposure to on-site airborne asbestos (because of lack of compacted soil cover) as compared to the soil covering with vegetation alternative or its variations.

Implementation of any of the alternatives is not expected to result in long-term threats to the safety of workers, nearby communities and environments.

5.1.5 SUMMARY OF TECHNICAL FEASIBILITY ANALYSIS

Table 5-1 summarizes, in matrix format, the relative desirability of alternatives in responding to the primary technical concerns at this site using a numerical designator for the least favorable to most favorable response alternative. Scores of 0 and 4 in the tables represent the extremes for the alternatives; 0 is the least favorable and 4 is most favorable. Intermediate values between 0 and 4 are used to rate an alternative in comparison to the other alternatives for related evaluation factors. Intermediate values are subjective, based on experience and engineering judgment. The basis for the scoring applied in Table 5-1 is described in Sections 5.1.1 through 5.1.4.

Based on the scores presented in Table 5-1, the desirability of the alternatives according to their technical feasibility, in the decreasing order, is as follows:

- Soil covering with vegetation or its variation

TABLE 5-1

RELATIVE DESIRABILITY OF ALTERNATIVES FOR CONTROL OF WASTE SOURCES(1) (TECHNICAL FEASIBILITY)

EVALUATION FACTOR	CRITERIA	ALTERNATIVE SCORE(2) NO ACTION	GRADING & SEEDING	SOIL COVERING * WITH VEGETATION	OFF-SITE LANDFILLING	ON-SITE(3) LANDFILLING
Performance	Proven Technology	0	2	3	4	3
	Degree of Ground Water Protection Provided	0	1	2	4	3
	Elimination of Direct Contact and Airborne Dispersion Pathways	0	2	3	4	3
	Useful Life	0	2	3	4	3
Reliability	Operation and Maintenance requirements	4	2	2	3	0
	Risk of Failure	0	1	2	4	3
Implementability	Constructability	4	3	3	1	0
	Time Required to Implement	4	3	3	1	0
	Time Required to achieve beneficial results	0	4	4	3	2
Safety	Workers	4	3	3	0	1
	Neighboring Facilities & Communities	4	2	2	0	1
TOTAL SCORE		20	25	30	28	19

(1) Sources defined as waste materials containing asbestos and lead (entire waste materials & sludges)
(2) Legend (relative scores):
4 -Most Favorable
3 - Favorable
2 - Intermediate
1 - Unfavorable
0 - Abortive
(3) Assumes on-site landfill concurrently developed to handle contaminated soils.
* Relative scores for its variations are same as for the primary alternative

- Off-site landfilling
- Grading and seeding
- No action
- On-site landfilling

5.2 INSTITUTIONAL REQUIREMENTS

This section includes evaluation of how well different alternatives comply with applicable or relevant local, state and federal environmental and public health standards, guidance or advisories. A discussion of the relevant regulations and levels of compliance achieved by different alternatives is presented in the following paragraphs

5.2.1 OVERVIEW OF INSTITUTIONAL REQUIREMENTS

The waste materials/soil at this site contain non-leachable lead and asbestos and are not classified as hazardous wastes. These wastes are classified as special wastes by different governmental agencies as special requirements exist pertaining to their handling and disposal. Johns-Manville Waukegan disposal area is a designated Superfund Site for remedial response to potential airborne asbestos emissions. In view of these facts, the following regulations are considered applicable or relevant.

1) CERCLA established NCP for Remedial Action (40 CFR 300)

2) USEPA Groundwater Protection Strategy (GWPS) and recommendation under Safe Drinking Water Act (SDWA)

3) Resource Conservation and Recovery Act (RCRA) requirements for facility siting and general operation of disposal sites (40 CFR Part 257)

4) National Emissions Standards for Hazardous Air Pollutants (NESHAP) under Clean Air Act (40 CFR 61 Subpart M)

5) OSHA regulations for the protection of workers for handling asbestos-containing materials (29 CFR Part 1910)

Local and State governments have requirements that are compatible with those above for specific site conditions. Local community input would also be required prior to selecting an alternative for implementation.

5.2.1.1 CERCLA (NCP) COMPLIANCE

According to NCP (40 CFR 300) a remedial response alternative must mitigate releases or threat of releases of contaminants which may present an imminent and substantial danger to public health and welfare. The remedial response objective at this site is to mitigate potential direct contact with the contaminants and exposure to airborne asbestos fibers.. The no action alternative does not meet this objective. Grading and seeding is expected to reduce airborne asbestos emissions and direct contact with contaminants. However, soil covering with vegetation alternative or its variation would provide more effective remedial response because of the added cover of compacted clean soils. In comparison to grading and seeding and soil covering with vegetation alternatives, the off-site and on-site landfilling alternatives would provide added protection to groundwater from the possible releases of lead.

5.2.1.2 USEPA GROUNDWATER PROTECTION STRATEGY (GWPS) COMPLIANCE

According to the USEPA guidelines under GWPS, the groundwater at this site is a Class 2 groundwater. A Class 2 groundwater is a current or potential source of Drinking Water. The goal of CERCLA cleanups is a drinking water quality for all Class 2 groundwater sources.

Proposed RMCL for asbestos in drinking water is 7.1 million fibers per liter. However, asbestos fibers greater than 5 microns in length were not detected in groundwater. The groundwater quality at this site is of Drinking Water Quality and does not need added protection. Therefore, all alternatives comply with GWPS. However, because of the use of impermeable liners , landfilling alternatives should be preferable over the grading and seeding, soil covering with vegetation and no action alternatives.

5.2.1.3 RCRA COMPLIANCE

RCRA has specific requirements (40 CFR Part 257) for siting and operating solid waste disposal facilities to minimize adverse effects of disposal facilities on health or the environment (which includes surface water and groundwater). In addition, other sections of RCRA have been considered and where appropriate incorporated in the alternatives. All alternatives comply with the applicable requirements. However, because of the use of impermeable liners the on-site and off-site landfilling alternatives should be preferable over the other alternatives.

5.2.1.4 NESHAP COMPLIANCE

NESHAP requirements for controlling asbestos emissions from the site are being met for the operation of the waste disposal pits. However, the closure requirements of 6" compacted non-asbestos-containing material/soil cover with vegetation will not be fulfilled by the no action and grading and seeding alternatives. All remaining alternatives comply with NESHAP requirements.

5.2.1.5 OSHA COMPLIANCE

OSHA regulations are established to protect workers handling asbestos-containing materials. All alternatives should comply with this. However, the off-site and on-site landfilling alternatives would require greater period of personal air monitoring because of larger quantities of material handling involved.

5.2.1.6 COMMUNITY REQUIREMENTS COMPLIANCE

Level of community interest in this project to date has been minimal. Some concerns expressed have been about the potential exposure to airborne asbestos emissions from the disposal area. Therefore, the no action alternative may not be the most desirable from the perception of community residents. Because of the increased short-term potential of exposure to asbestos fibers of the on-site and the off-site landfilling alternatives, the community residents may prefer soil covering with vegetation alternative or its variation over other alternatives.

5.2.1.7 SUMMARY OF INSTITUTIONAL REQUIREMENTS ANALYSIS

Table 5-2 summarizes, in matrix format, the relative desirability of alternatives in responding to the relevant institutional requirement using a numerical designator for the least favorable to most favorable response alternative. Scores of 0 and 4 in the tables represent the extremes for the alternatives; 0 is the least favorable and 4 is most favorable. Intermediate values between 0 and 4 are used to rate an alternative in comparison to the other alternatives for related evaluation factors.

Intermediate values are subjective, based on experience and engineering judgment. The basis for the scoring applied in Table 5-2 is described in Sections 5.2.1.1 through 5.2.1.6.

Based on the scores presented in Table 5-2, the desirability of the alternatives according to their compliance with institutional requirements, in the decreasing order, is as follows:

- Soil covering with vegetation or its variation
- On-site landfilling
- Off-site landfilling
- Grading and seeding
- No action

5.3 PUBLIC HEALTH REQUIREMENTS

This section includes evaluation of different alternatives with respect to their effectiveness in mitigating threats from contaminants to human health and environment both during and after the implementation of the remedial alternatives. A detailed discussion of the contaminants, routes of migration, exposure assessment and risk assessment is presented in the Final Remedial Investigation Report. A summary of the level of endangerment to human health and environment posed by potential or actual release of hazardous substances from the site is presented in Section 2.2.6. An evaluation of the effectiveness of different alternatives in achieving the relevant environmental standards or mitigating assessed endangerment is presented in the following paragraphs.

TABLE 5-2

RELATIVE DESIRABILITY OF ALTERNATIVES
FOR CONTROL OF WASTE SOURCES (1)
(COMPLIANCE WITH INSTITUTIONAL REQUIREMENTS)

EVALUATION FACTOR	ALTERNATIVE SCORE(2) NO ACTION	GRADING & SEEDING	SOIL COVERING * WITH VEGETATION	OFF-SITE LANDFILLING	ON-SITE(3) LANDFILLING
CERCLA Compliance	0	2	3	4	4
EPA GWPS Compliance	0	2	3	4	4
RCRA Compliance	0	2	3	4	4
NESHAP Compliance	0	1	4	4	4
OSHA Compliance	4	3	3	0	0
COMMUNITY REQUIREMENTS Compliance	0	3	4	0	1
TOTAL SCORE	4	13	20	16	17

(1) Sources defined as waste materials containing asbestos and lead (entire waste materials & sludges)

(2) Legend (relative scores):
4 - Most Favorable
3 - Favorable
2 - Intermediate
1 - Unfavorable
0 - Abortive

(3) Assumes on-site landfill concurrently developed to handle contaminated soils.

* Relative scores for its variations are same as for the primary alternative

5.3.1 OVERVIEW OF RELEVANT ENVIRONMENTAL STANDARDS

The following standards are considered relevant for the evaluation of remedial alternatives at this site.

Lead:

Safe Drinking Water Act, Maximum Contaminant Level (MCL) = 0.05 mg/l

Clean Air Act, National Ambient Air Quality Standard (NAAQS) = 1.5 ug/m^3

Clean Water Act, Water Quality Criteria for Human Health, Fish and Drinking Water = 50 ug/l
Clean Water Act, Water Quality Criteria for Human Health, adjusted for drinking water only = 50 ug/l
(Derived from EPA Water Quality Criteria 45 FR 79318-79379 November 28, 1980)

Asbestos:

Proposed RMCL of 7.1 million fibers per liter (for medium and long fibers i.e. greater than 10 microns in length) by USEPA is the only relevant standard or guideline for drinking water.

Only relevant asbestos in ambient air standard is NESHAP "no visible emissions" standard.

Lead level in the air or groundwater samples was always less than the standard prescribed to protect public health, based on RI sampling. No visible emissions of asbestos from the site have been observed during RI work. No asbestos fibers longer than 5 microns were detected in the groundwater and observed values for surface water were well within the proposed RMCL.

5.3.2 PUBLIC HEALTH EVALUATION

All relevant air and groundwater standards appear to be met at this site based on RI sampling. However, potential threat to human health exists from direct contact with the waste materials or through exposure to potential airborne asbestos emissions. Under no action alternative, the potential of exposure of Manville employees, working on the site, to lead and airborne asbestos fibers would remain.

Under grading and seeding alternative, the potential for on-site airborne asbestos emissions and direct contact with lead-containing waste materials will decrease but may not be eliminated. Also, adverse short-term impact may occur due to increased level of airborne asbestos emissions during construction activities. Each of the soil covering with vegetation, on-site and off-site landfilling alternatives provides adequate protection to human health after the implementation of the alternative. However, in the short-term the off-site landfilling is estimated to provide greater threat to public health due to increased material handling and transportation involved. Short-term potential of human exposure to lead and airborne asbestos emissions is estimated to be less for the soil covering with vegetation alternative or its variation than for the on-site or off-site landfilling. Each of these three alternatives will assure compliance with the environmental standards in the long-term.

5.3.3 SUMMARY OF PUBLIC HEALTH ANALYSIS

Table 5-3 summarizes, in matrix format, the relative desirability of alternatives in responding to the relevant public health requirements using a numerical designator for the least favorable to most favorable response alternative. Scores of 0 and 4 in the tables represent the extremes for the alternatives; 0 is the least favorable and 4 is most favorable. Intermediate values between 0 and 4 are used to rate an alternative in comparison to the other alternatives for related evaluation factors. Intermediate values are subjective, based on experience and engineering judgment. The basis for the scoring applied in Table 5-3 is described in Section 5.3.2.

Based on the scores presented in Table 5-3, the desirability of the alternatives according to their compliance with Public Health requirements, in the decreasing order, is as follows:

- Soil covering with vegetation or its variation
- Grading and seeding
- Off-site landfilling
- On-site landfilling
- No action

TABLE 5-3

RELATIVE DESIRABILITY OF ALTERNATVES
FOR CONTROL OF WASTE SOURCES (1)
(COMPLIANCE WITH PUBLIC HEALTH REQUIREMENTS)

EVALUATION FACTOR	ALTERNATIVE SCORE(2) NO ACTION	GRADING & SEEDING	SOIL COVERING WITH VEGETATION *	OFF-SITE LANDFILLING	ON-SITE(3) LANDFILLIN
Compliance with Air Requirements					
During Implementation					
Lead	4	3	2	0	1
Asbestos	4	3	2	0	1
After Cleanup					
Lead	0	2	4	4	4
Asbestos	0	2	4	4	4
Compliance with Water Quality Requirements					
During Implementation					
Lead	4	3	2	1	0
Asbestos	4	3	2	1	0
After Cleanup					
Lead	0	1	2	4	3
Asbestos	0	1	2	4	3
TOTAL SCORE	16	18	20	18	16

(1) Sources defined as waste materials containing asbestos and lead (entire waste materials and sludges)
(2) Legend (relative scores):
4 - Most Favorable
3 - Favorable
2 - Intermediate
1 - Unfavorable
0 - Abortive
(3) Assumes on site landfill concurrently developed to handle contaminated soils.
* Relative scores for its variations are same as for the primary alternative

5.4 ENVIRONMENTAL IMPACTS

This section includes environmental assessment of proposed remedial alternatives. The environmental assessment discusses the adverse environmental impacts of the site problems, pathways of contamination and an evaluation of the relative effectiveness of the proposed alternatives in achieving adequate protection and improvement of the environment.

5.4.1 OVERVIEW OF ENVIRONMENTAL ASSESSMENT

Lead and asbestos-containing waste materials/soil at this site appear to have not degraded the quality of air, surface water and groundwater in the vicinity of the site so as to violate their respective environmental standards. There has been no documented adverse impact on the human and wildlife population or residential, commercial and recreational activities in the vicinity of the site. Some of the on-site air samples contained asbestos fibers at levels somewhat higher than those observed at the off-site locations. There has been no documented discharge of pollutants to surface and/or groundwater from the disposal area. In fact, there has been significant reduction in the process water flows and quantity of asbestos-containing waste materials treated/disposed at this site. Future disposal of asbestos-containing waste materials is expected to diminish to insignificant levels and cease by 1989.

There are no known environmentally sensitive resources or areas such as wetlands, prime and unique agricultural lands, aquifer recharge zones, archealogical and historical sites and endangered and threatened species, in the vicinity of the site.

5.4.2 EVALUATION OF ALTERNATIVE RESPONSES

The environmental affects of alternatives have been divided into the following two categories:

- Beneficial effects
- Adverse effects

A discussion of primary (direct) and secondary (indirect) effects of proposed alternatives under these two categories are presented in the following paragraphs.

5.4.2.1 BENEFICIAL EFFECTS

Three evaluation factors were considered to evaluate beneficial effects of alternatives. These are as follows:

- Changes in the release of contaminants and final environmental conditions
- Improvements in the biological environment
- Improvements in resources people use.

Under no action alternative, there will be no change in the environmental conditions on the site, biological environment and resources. In the short-term, there will be considerable savings in the commitment of energy and other irreversible resources. Grading and seeding will diminish the potential for on-site airborne asbestos emissions and direct contact with waste materials/soil containing lead and asbestos. There will be an improvement in the site air quality after the implementation of this alternative. A limited amount of improvements in the biological environment and resources in the vicinity of the site are estimated from the implementation of grading and seeding or soil covering with vegetation alternatives. Improved vegetation and shrubbery is likely to increase productivity of wildlife harboring in the area, as well as improve aesthetics of the site for Manville employees working on the site and public using Lake Michigan beach.

Soil covering with vegetation or its variation will eliminate potential direct contact and airborne asbestos exposure pathways and also provide some groundwater protection. On-site and off-site landfilling alternatives will eliminate potential direct contact and airborne asbestos exposure pathways as well as provide protection to groundwater and surface water from potential contamination by leached lead, if any is ever present. Also more land will be available along the Lake Michigan Shore because of the removal of deposited waste materials in the on-site or off-site landfill alternative.

5.4.2.2 ADVERSE EFFECTS

Two evaluation factors were considered for adverse effects of alternatives. These are as follows:

- Effects of remedial construction and operations on sensitive environmental areas and resources people use

- Effectiveness of mitigating measures employed during construction and operation to minimize adverse environmental impacts.

Because of the longest implementation time of on-site landfilling alternative, there would be longer exposure of public and wildlife to lead, airborne asbestos, dust and noise. A properly designed and implemented program involving wetting of waste materials, personal monitoring, use of warning signs and protective health and safety equipment during construction would be required to minimize the short-term adverse public health impacts. As compared to off-site landfilling, the land use would be restricted in the on-site landfill area because of the irreversible commitment of land. The use of this land may also adversely impact the productivity of the wildlife in the area. On-site landfilling alternative also requires irreversible commitment of large amounts of energy and other resources. The mitigating measures employed during waste handling and construction of activities should minimize potential exposure to airborne asbestos emissions during implementation of different alternatives.

The short-term and long-term adverse environmental impacts of off-site landfilling alternative would be similar to that of on-site landfilling except that the off-site landfilling alternative will involve somewhat shorter period of construction generated pollution (e.g. noise, dust) and greater risk of transportation accidents. A properly managed and executed waste removal and hauling operations would limit short-term adverse impacts to acceptable levels as discussed earlier.

In the short-term, grading and seeding as well as soil covering with vegetation alternatives may increase level of airborne asbestos fibers in the vicinity of the construction area. This may have adverse impact on workers on a temporary basis. The adverse impact however, will be much less than that from on-site and off-site landfilling alternatives because of reduced material handling involved. In the long-term, no action and grading and seeding alternatives would provide limited protection to groundwater. Soil covering with vegetation or its variation would provide greater groundwater protection due to reduction in the infiltration flow.

In the no action alternative, the potential of exposure of Manville employees working on the site and wildlife harboring in the vicinity of the site, to lead and asbestos fibers, will remain for a long time.

5.4.3 SUMMARY OF ENVIRONMENTAL ANALYSIS

Table 5-4 summarizes, in matrix format, the relative desirability of alternatives with respect to their environmental impacts using a numerical designator for the least favorable to most favorable response alternative. Scores of 0 and 4 in the tables represent the extremes for the alternatives; 0 is the least favorable and 4 is most favorable. Intermediate values between 0 and 4 are used to rate an alternative in comparison to the other alternatives for related evaluation factors. Intermediate values are subjective, based on experience and engineering judgment. The basis for the scoring applied in Table 5-4 is described in Sections 5.4.2.1 and 5.4.2.2.

Based on the scores presented in Table 5-4, the desirability of the alternatives according to their environmental impacts, in the decreasing order, is as follows:

- Soil covering with vegetation or its variation
- Grading and seeding
- Off-site landfilling
- No action
- On-site landfilling

5.5 COST ANALYSIS

This section includes estimates of capital and operation and maintenance (O & M) costs for remedial action alternatives. A present worth analysis as well as a sensitivity analysis (sensitivity of cost estimates to changes in assumptions) of these costs are also presented to facilitate relative comparison of proposed alternatives on the basis of their capital and O & M costs.

TABLE 5-4

RELATIVE DESIRABILITY OF ALTERNATIVES
FOR CONTROL OF WASTE SOURCES (1)
(BASED ON ENVIRONMENTAL IMPACTS)

EVALUATION FACTOR	ALTERNATIVE SCORE(2) NO ACTION	GRADING & SEEDING	SOIL COVERING * WITH VEGETATION	OFF-SITE LANDFILLING	ON-SITE(3) LANDFILLING
Beneficial Effects					
Final Environmental Conditions	0	1	2	4	3
Improvements in Biological Environment	1	3	4	2	0
Improvements in Human Use Resources	0	1	2	4	3
Adverse Effects					
Construction/Operation	4	3	3	0	1
Mitigating Measures	4	3	3	0	1
TOTAL SCORE	9	11	14	10	8

(1) Sources defined as waste materials containing asbestos and lead (entire waste materials and sludges)
(2) Legend (relative scores):
4 - Most Favorable
3 - Favorable
2 - Intermediate
1 - Unfavorable
0 - Abortive
(3) Assumes on site landfill concurrently developed to handle contaminated soils.

* Relative scores for its variation are same as for the primary alternative

5.5.1 COSTING METHODOLOGY

A preliminary conceptual design of an alternative was used to estimate the equipment, labor and material requirements of each of the tasks required to implement, operate and maintain that alternative. Major contractors and vendors in the Waukegan, Illinois area were contacted for unit and lump sum costs, as appropriate. These costs were further adjusted to reflect site conditions using bids on similar recent projects.

This site is being operated and maintained for treatment/disposal of process water and manufacturing waste materials by Manville staff. Therefore, the costs associated with operation and maintenance of any remedial action alternative are the estimated increment in the present operation and maintenance costs. All O & M cost estimates have been prepared using this approach.

5.5.2 CAPITAL COSTS

Estimated capital costs of the proposed remedial action alternatives are presented in Appendix A. These cost estimates are based on 1986 dollars. These include direct (construction) costs and indirect (non-construction and overhead) costs. The indirect costs included are for design engineering, construction management and contingencies (for change orders and other unforeseen circumstances). None of the alternatives involve phasing of work. The estimated capital costs vary from $15,000 for the no action alternative to $70,565,000 for the off-site disposal alternative.

5.5.3 OPERATION AND MAINTENANCE COSTS

Estimated annual O & M costs of each of the proposed remedial action alternatives based on 1986 dollars, are presented in Appendix A. These include labor, material, energy and surface water and groundwater monitoring costs as well as allowance for administrative and contingency expenses. The estimated annual O & M costs vary from $33,000 for the no action alternative to $300,000 for the off-site disposal alternative. A significant portion of the latter is due to future off-site disposal of waste materials generated at the plant.

5.5.4 CASH FLOW REQUIREMENT

Cash flow requirements over the life of each of of the remedial action alternatives is presented in Appendix A.

5.5.5 PRESENT WORTH ANALYSIS

A present worth figure represents the amount of money, that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action alternative over its planned life. Present worth analysis was made using 1986 as the base year and a discount rate of 10% and the planned life (period of performance) of 30 years. Present worth analysis for each of the proposed remedial action alternatives is presented in Appendix A. The present worth varies from $326,090 for the no action alternative to $73,393,100 for the off-site disposal alternative.

5.5.6 SENSITIVITY ANALYSIS

A sensitivity analysis assesses the effect that variations in specific assumptions associated with the design, implementation, operation, discount rate, and effective life of an alternative can have on the estimated cost of the alternative. Based on the examination of the capital and O & M costs of proposed alternatives two assumptions were varied for sensitivity analysis. An analysis based on a discount rate of 4% and an effective life of 15 years is presented in Table 5-5. This analysis shows that the relative present worth of the proposed remedial action alternatives is not sensitive to the discount rate and/or effective life assumptions.

5.5.7 SUMMARY OF COST ANALYSIS

A summary of cost analysis of alternatives is included in Table 5-5. The on-site and off-site landfilling alternatives are the two most costly alternatives. O & M costs of alternatives are relatively small compared to their capital costs except for the no action alternative. Present worth cost of soil covering with vegetation alternative or its variation is more than that of grading and seeding alternative but significantly less than those of off-site and on-site disposal alternatives.

Table 5-6 summarizes, in matrix format, the relative desirability of alternatives with respect to their cost analysis using a numerical designator for the least favorable to most favorable response alternative. Scores of 0 and 4 in the tables represent the extremes for the alternatives; 0 is the least favorable and 4 is most favorable. Intermediate values between 0 and 4 are used to rate an alternative in comparison to the other alternatives for related evaluation factors. Intermediate values are subjective, based on experience and engineering judgment. The basis for the scoring applied in Table 5-6 is the cost analysis data presented in Table 5-5 and cost certainty judgement.

TABLE 5-5 PRESENT WORTH ANALYSIS OF ALTERNATIVES

Alternative	Cost Estimates ($1,000) Capital	Cost Estimates ($1,000) O & M	Present Worth ($1,000) 15 Year Life 4% (1)	Present Worth ($1,000) 15 Year Life 10% (2)	Present Worth ($1,000) 30 Year Life 4% (3)	Present Worth ($1,000) 30 Year Life 10% (4)
1. No action	15	33	382	266	586	326
2. Grading and Seeding	2,615	54	3,215	3,025	3,549	3,124
3. Soil Covering with vegetation (18" cover)	3,624	49	4,169	3,996	4,471	4,086
3a. Soil Covering with vegetation (24" cover)	4,026	49	4,571	4,398	4,873	4,488
3b. Soil Covering with vegetation (30" cover)	4,427	49	4,972	4,799	5,274	4,889
4. Off-site landfilling	70,565	300	73,899	72,843	75,753	73,393
5. On-site landfilling	38,555	80	39,444	39,162	39,938	39,309
Ranking (Lowest to Highest Cost Alternative)	1,2,3, 3a,3b,5,4	1,3,3a,3b, 2,5,4	1,2,3,3a, 5,4	1,2,3,3a, 3b,5,4	1,2,3,3a, 3b,5,4	1,2,3,3a, 3b,5,4

(1) Present worth factor for 15 years = 11.113 at 4%
(2) Present worth factor for 15 years = 7.593 at 10%
(3) Present worth factor for 30 years = 17.292 at 4%
(4) Present worth factor for 30 years = 9.427 at 10%

TABLE 5-6

RELATIVE DESIRABILITY OF ALTERNATIVES
FOR CONTROL OF WASTE SOURCES (1)
(BASED ON COST ANALYSIS

EVALUATION FACTOR	NO ACTION	GRADING & SEEDING	SOIL COVERING WITH VEGETATION 18"	24"	30"	OFF-SITE LANDFILLING	ON-SITE(3) LANDFILLING
	ALTERNATIVE SCORE(2)						
CAPITAL COST	4	3	3	2	2	0	1
OPERATION AND MAINTENANCE COST	4	3	3	3	3	0	2
COST CERTAINTY	4	3	3	3	3	0	1
TOTAL SCORE	12	9	9	8	8	0	4

(1) Sources defined as waste materials containing asbestos and lead (entire waste materials and sludges)
(2) Legend (relative scores):
4 - Most Favorable
3 - Favorable
2 - Intermediate
1 - Unfavorable
0 - Abortive
(3) Assumes on site landfill concurrently developed to handle contaminated soils.

Based on the scores presented in Table 5-6, the desirability of the alternatives according to their cost analysis, in the decreasing order, is as follows:

- No Action
- Grading and seeding
- Soil covering with vegetation or its variation
- On-site landfilling
- Off-site landfilling

6.0 SUMMARY OF ALTERNATIVES AND RECOMMENDATIONS

Five alternatives were selected, after initial screening of available alternatives, for contaminant source control remedial response. The primary objective of the remedial action alternatives at this site is to mitigate potential direct contact and airborne asbestos dispersion pathways. Scope of work in each of these alternatives was discussed in details in Section 4.0. These alternatives were evaluated for technical feasibility, institutional requirements, public health and environmental impacts, capital and operation and maintenance costs. Details of these evaluations are presented in Section 5.0. The following paragraphs present a summary of alternatives and results of their analysis pointing out their relative advantages and disadvantages. Also included is the recommended alternative along with the basis for its selection.

6.1 SUMMARY OF ALTERNATIVES

The following five alternatives were selected after screening of available alternatives using public health and environment impacts and cost screening.

1. <u>No Action</u>

   This alternative involves leaving the wastes on the disposal area in their current state. The groundwater and surface water would however be monitored bi-annually to assure that water quality is not degraded in future.

2. <u>Grading and Seeding</u>

   This alternative involves grading of waste materials/soil and laying a 3" thick layer of top soil on all surfaces except the roadways and top dikes. All surfaces covered with top soil would be fertilized and seeded. In addition, a minimum cover of 24" clean soil on top of dikes, 4" to 8" thick gravel on all-weather dike roadways, nominal 12" thick riprap with 4" thick bedding on interior slopes of settling basins would be provided where it is feasible to place riprap. The groundwater and surface water would be sampled annually and analyzed for lead and other organic and inorganic water quality parameters. The three active waste disposal areas would continue to be used for current and future waste disposal. Written waste handling procedures would be provided to the staff working at the site for asbestos disposal pit, the miscellaneous pit, and the sludge disposal pit. However, the asbestos disposal pit would be closed in 1989. In future, any asbestos-containing waste generated would be disposed off-site in an approved facility.

3. Soil Covering With Vegetation

This alternative and its variations involve grading of waste materials/soil, covering with 15" to 27" (depending on the variation) compacted non-asbestos-containing soil and laying a 3" thick layer of top soil on all surfaces except the roadways and top of dikes. All surfaces covered with top soil would be fertilized and seeded. In addition, a minimum cover of 24" clean soil on top of dikes, 4" to 8" thick gravel on all-weather dike roadways, nominal 12" thick riprap with 4" thick bedding on interior slopes of settling basins would be provided where it is feasible to place riprap. The groundwater and surface water would be sampled annually and analyzed for lead and other organic or inorganic water quality parameters. The three active waste disposal areas (sludge disposal pit, asbestos disposal pit and miscellaneous disposal pit) would continue to be used for current and future waste disposal. Written waste handling procedures would be provided to the staff working at the site for asbestos disposal pit, the miscellaneous disposal pit, and the sludge disposal pit. However, the asbestos disposal pit would be closed in 1989. In future, any asbestos-containing waste generated would be disposed off-site in an approval facility.

4. Off-Site Landfilling

This alternative involves removal and off-site disposal of the entire waste materials/soil at this site. These would include all materials in the waste piles, sludge pit and other disposal pits plus all of the materials in the dikes of the process water treatment basins and the wet sludge in these basins. These wastes are classified as special wastes but not as hazardous wastes. In this alternative all waste would be excavated, loaded and transported to permitted landfilling facilities for final disposition. The process water treatment-basins would be rebuilt and monitoring of local groundwater and surface water would continue to assure that all contributory sources from the site had been removed and that the groundwater and surface water is not degraded in the future by the process water treatment basins. In future, all waste materials/soil generated at the Waukegan facilities would be disposed in approved off-site landfills.

5. On-Site Landfilling

This alternative involves removal and disposal of the entire waste materials/soil to an on-site landfill designed and constructed specifically for the disposal of Johns-Manville Waukegan waste materials. These would include all materials in the waste piles, waste disposal pits, settling basin dikes and the wet sludge in the settling basins. A landfill would be constructed on the northwest corner of the Manville plant property. All wastes would be excavated and transported to this landfill for disposal, and this portion of the landfill would be closed. A portion of this landfill would be kept active for the disposal of all current and future waste materials from the Manville facilities.

The process water treatment basins would be rebuilt and monitoring of local groundwater and surface water would continue to assure that all contributory sources from the site had been removed and that the groundwater and surface water quality is not degraded in the future by the process water treatment basins and the on-site landfill.

6.2 SUMMARY OF ANALYSIS OF ALTERNATIVES

A summary of analysis of each of the five alternatives for technical feasibility, institutional requirements, public health and environmental impacts, capital and O & M costs is presented below:

1. No Action

   The potential of human and wildlife exposure to on-site asbestos fibers and lead would continue to exist. The site would not meet remedial response objectives and requirements of CERCLA and NESHAP regulation for asbestos disposal sites. There may also be public opposition to this alternative. In the short-term, there would be considerable savings in the commitment of natural resources, energy and money. However, in the long-term the environment and public health may be adversely impacted.

   No action is the least Capital and O & M costs alternative.

2. Grading and Seeding

   This alternative is technically feasible and would be expected to diminish the potential for on-site airborne asbestos emissions and direct contact with waste materials/soil containing lead. However, it would provide poor groundwater protection and 3" top soil cover would not meet the NESHAP regulation for asbestos disposal sites. A limited potential of human and wildlife exposure to asbestos fibers and lead may continue to exist. The site may therefore not fully meet the remedial response objectives and the requirements of CERCLA. There may also be public opposition to this alternative. Adverse short-term impacts on public health and environment may occur due to increased level of airborne asbestos during constructions activities. However, these adverse impacts would be less than those for on-site and off-site landfilling alternatives. In the short-term, there would be reduced commitment of energy, money and natural resources due to reduced use of materials as opposed to soil covering or other alternatives. However, in the long-term the environment and public health may be adversely impacted.

Grading and seeding alternative has the second lowest present worth cost of all the alternatives.

3. <u>Soil Covering With Vegetation</u>

This alternative or its variation uses readily available and proven technology and is expected to eliminate the potential for on-site airborne asbestos emissions and direct contact with waste materials/soil containing lead and asbestos. In addition, prpvisions of SARA of 1986 have been considered and a monitoring program for the soil cover, to be mutually agreed upon by USEPA and Manville, will be developed to attain the new cleanup standards contained in Section 121 of SARA. This alternative or its variation meets NESHAP requirement for asbestos disposal sites as well as the remedial response objectives of CERCLA. This alternative or its variation would also provide some protection to groundwater from potential contamination by leachable lead although less than that by on-site or off-site landfilling alternatives. However, the groundwater contamination is not of primary concern at this site because of the presence of lead in the encapsulated and not readily leachable forms.

Adverse short-term impacts on public health and environment may occur from this alternative or its variation due to increased level of airborne asbestos in the vicinity of the construction area. However, these adverse impacts would be less than those of on-site and off-site landfilling alternatives. An extensive program of wetting waste materials, personal monitoring, use of warning signs and appropriate protective health and safety equipment during construction would minimize these short-term adverse impacts.

In the short-term, there would be reduced commitment of energy, money and natural resources as opposed to on-site and off-site landfilling alternatives. In the long-term, there would be improvements in the biological environment and resources in the vicinity of the site..

This alternative or it variation has relatively low capital and O & M costs as compared to off-site and on-site landfilling alternatives.

4. Off-Site Landfilling

This alternative uses readily available and proven technologies but relies on the available landfill capacity in the existing landfills in the Waukegan area. The available capacity relative to the disposal needs of this site is limited. In the long-term, this alternative would provide adequate protection to human health and environment in the vicinity of the site.

It would also protect groundwater and surface water from potential contamination by leachable lead, if any is ever present. Because of the relatively longer implementation time and greater risks of transportation accidents of this alternative, there would be longer exposure of public and wildlife to lead, airborne asbestos, dust and noise as compared to soil covering with vegetation alternative. In the long-term, this alternative would make available more land along the Lake Michigan Shore.

This alternative involves large commitment of energy, money and commercial landfill capacity and has the highest Capital and O & M costs of all the alternatives.

5. On-Site Landfilling

This alternative is technically feasible. Its short-term and long-term health and environmental impacts would be similar to that of off-site landfilling except that the off-site landfilling alternative involves longer transportation distances. On-site landfilling has the longest implementation time of all the alternatives and hence greater construction generated pollution (e.g., noise, dust). On-site landfilling alternative would provide adequate contaminant source control including groundwater protection. This alternative would involve the use of land near the on-site landfill location and may adversely impact the biological environment in the area.

This alternative involves relatively large commitment of energy, money and resources and has second highest Capital and O & M costs of all the alternatives.

6.3 RECOMMENDED ALTERNATIVE

A summary of costs, public health, environmental, technical and community response concerns for each of the remedial action alternatives is presented in Table 6-1. Also included in this table is the total score of each alternative obtained by adding alternative analysis scores from Tables 5-1 through Table 5-4 and Table 5-6.

TABLE 6-1 REMEDIAL ACTION ALTERNATIVE EVALUATION SUMMARY

Alternative	Cost ($1,000) Capital	Cost ($1,000) Present Worth(1)	Public Health Concerns	Enviromental Concerns	Technical Concerns	Community Response Concerns	Composite Score From Analysis
No Action	15	326	Lead & asbestos exposure Airborne asbestos	Limited protection for migration to groundwater. No contamination documented	-	May not be acceptable	61
Grading and Seeding	2,615	3,124	Limited exposure to lead and asbestos	Limited improvements for lead migration to groundwater Improved landscape		May be acceptable	76
Soil Covering with Vegtation(2)	3,624	4,086	Eliminates exposure to lead and asbestos	Limited improvements for lead migration to groundwater, improved landscape and biological productivity of wildlife	-	Acceptable	93
Soil Covering with 24" Cover	4,026	4,488	Eliminates exposure to lead and asbestos	Limited improvements for lead migration to groundwater, improved, landscape and biological productivity of wildlife		Acceptable	92
Soil Covering with 30" Cover	4,427	4,889	Eliminates exposure to lead and asbestos	Limited improvements for lead migration to groundwater, imroved, landscape and biological productivity of wildlife		Acceptable	92
Off-Site Landfilling	70,565	73,393	Eliminates exposure Greater short-term airborne asbestos	Eliminates potential of lead Large comittment of resources	Longer implementa- Large quantities of waste	May not be acceptable	72
On-Site	38,555	39,309	Eliminates exposure Greater short-term airborne asbestos	Minimal potential of lead migration, large commitment of resources, may impact biological productivity of wildlife	Longer implementa-tion time, landfill siting approvals required	May not be acceptable	64

(1) Using 10% discount rate and 30 years effective life.
(2) Recommended alternative for remedial action (18" cover soil thickness).

Considering technical feasibility, public health and environmental impacts, fulfillment of institutional requirements and present worth costs, the soil covering with vegetation with 18" thick soil cover is the most desirable alternative for this site. The two variations of this alternative although have public health and environment impacts similar to that of the primary alternative (18" soil cover) but require increased commitment of energy, monetary and other resources.

This alternative involves appropriate treatment and disposal technologies that meet CERCLA and NESHAP requirements. In addition, provisions of SARA have been considered and a monitoring program for the soil cover, to be mutually agreed upon by USEPA and Manville , will be developed to attain the new cleanup standards contained in Section 121 of SARA.

This alternative involves shorter implementation time as well as lesser commitment of energy, money and other resources compared to on-site or off-site landfilling alternatives. No special studies or permits or approvals are needed for its implementation and no off-site disposal or temporary storage of contaminated waste is required. This alternative also provides some protection to groundwater from potential contamination of leachable lead and includes groundwater monitoring. However, the groundwater contamination is not of primary concern at this site because of the presence of lead in its encapsulated and not readily leachable forms.

It has less adverse public health and environmental impacts during implementation than on-site and off-site landfilling alternatives and is estimated to benefit the landscape and wildlife around the disposal area.

The adverse impacts on public health and environment that may occur during implementation are due to increased level of airborne asbestos, dust and noise pollution. However, these adverse impacts will be mitigated through limiting access to active construction area, wetting the active construction area prior to grading and waste handling, monitoring workers for exposure to airborne asbestos and using Level C protection (use of respirators, coveralls, gloves, foot and head covering) during grading and waste handling.

This alternative has relatively low operation and maintenance requirements. The current Manville O & M Staff is somewhat familiar with the O & M requirements of soil covering with vegetation alternative. Groundwater and surface water sampling and analysis will be performed by independent consultants. The Manville staff is capable of maintaining vegetation (grasses and shrubs) proposed under this alternative.

Soil covering with vegetation alternative using a total of 18" thick cover is therefore recommended for remedial action at this site. It is estimated to have a Capital cost of $3,624,170 and an annual O & M cost of $49,000 and is estimated to be implemented by the end of 1988. A preliminary implementation schedule is presented in Table 6-2.

TABLE 6-2 PRELIMINARY IMPLEMENTATION SCHEDULE FOR THE RECOMMENDED ALTERNATIVE

TENTATIVE DATE	DESCRIPTION OF TASK
January 13, 1987	Submit revised feasibility study report
January, 1987	Public notice for comments
February, 1987	Receive public notice comments
February, 1987	Complete plans and specifications for recommended remedial action alternative
March, 1987	Advertise for bids
April, 1987	Receive bids
May, 1987	Award Contract
May, 1987	Start construction
December, 1988	Complete construction

APPENDIX A

ESTIMATED CAPITAL,
OPERATION & MAINTENANCE COSTS,
PRESENT WORTH CALCULATIONS
AND
CASH FLOW REQUIREMENTS
OF
REMEDIAL ACTION ALTERNATIVES

ALTERNATIVE I: NO ACTION

COST ESTIMATES

1.	Estimated Capital Cost	$15,000.00
2.	Estimated annual Operation and Maintenance Costs:	
	Groundwater and surface water monitoring (twice/year)	$28,000.00
	Admimistrative and contingency costs	5,000.00
	TOTAL OPERATION & MAINTENANCE COSTS	$33,000.00
3.	Present Worth Analysis:	
	Present worth of capital cost	$15,000.00
	Present worth of Operation & Maintenance Cost*	$311,090.00
	TOTAL PRESENT WORTH	$326,090.00

* Based on a discount rate of 10% and a performance period of 30 years.

ALTERNATIVE II: GRADING AND SEEDING

COST ESTIMATES

1. Estimated Capital Costs:

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Mobilization, set-up, & other fixed costs (1)	LS	Job	75,000	75,000
Clearing & Grubbing	Acre	70	500	35,000
Excavation & Grading				
Balance cut & fill	CY	30,330	6.00	182,000
Extra Fill	CY	21,000	6.00	126,000
Roadways Cover Soil	CY	26,000	7.00	182,000
Top Soil (Min. 3" thick)	CY	28,000	9.00	252,000
Gravel Roadways				
Heavy Traffic Roadways (8" gravel over 24" cover)	LF	8,400	20.00	168,000
Light Traffic Roadways (4" gravel over 24" cover)	LF	9,200	5.00	46,000
Drainage Structures				
Northeast Ditch	LS	Job	55,000	55,000
Southeast Ditch	LS	Job	31,000	31,000
Slope Protection				
Settling Basins	SY	6,100	13.00	79,300
Paper Mill Effluent and Flex Board Effluent Catch & Mixing Basins	SY	6,100	13.00	79,300
Collection Basin	SY	1,200	13.00	15,600
East Ditch (Upstream Face)	LS	Job	25,000	25,000
East Ditch (Downstream Face)	LS	Job	50,000	50,000
Drainage				
Dike Drainage (French drains with filter fabric)	LF	2,000	21.00	42,000

ALTERNATIVE II: GRADING AND SEEDING

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Drainage Ditches	LF	11,000	4.00	44,000
Misc . Drainage Structures	LS	Job	10,000	10,000
Hydromulch	AC	70	3,000	210,000
Pond dredging & misc site cleanup (2)	LS	Job	200,000	200,000
Water sprays for dust suppressing	Day	125	400	50,000
Sub-Total				$1,957,200
Engineering	LS	Job	120,000	120,000
Construction Management Including chemical analysis of borrowed fill & top soil	LS	Job	300,000	300,000
Sub-Total				$2,377,200
Contingencies (10%)				237,720
TOTAL CAPITAL COST				$2,614,920

2. Estimated Annual Operation & Maintenance Costs:

Groundwater and Surface Water Monitoring (once/year)	$14,000
Labor & Material for Soil Cover and Vegetation and roadway maintenance	30,000
Administrative & Contingency Costs	10,000
TOTAL OPERATION & MAINTENANCE COST	$54,000

3. Present Worth Analysis:

Present Worth of Capital Cost	$2,614,920
Present Worth of Operation & Maintanence Cost	509,060
TOTAL PRESENT WORTH	$3,123,980

(1) Includes temporary fencing, security , health & safety & environmental monitoring and decontamination facilities for heavy equipment.

(2) Includes fencing along eastern site boundry, additional signs, beach cleanup and black ditch piping up to existing lift station.

ALTERNATIVE III: SOIL COVERING WITH VEGETATION

COST ESTIMATES

1. Estimated Capital Costs:

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Mobilization, set-up, & other fixed costs (1)	LS	Job	80,000	80,000
Clearing & Grubbing	Acre	70	500	35,000
Excavating & Grading				
Balance cut & fill	CY	30,330	6.00	182,000
Extra Fill	CY	21,000	6.00	126,000
Roadways Cover Soil	CY	26,000	7.00	182,000
Cover Soil (15" thick)	CY	125,000	6.50	812,500
Top Soil (3" thick)	CY	28,000	9.00	252,000
Gravel Roadways				
Heavy Traffic Roadways (8" gravel over 24" cover)	LF	8,400	20.00	168,000
Light Traffic Roadways (4" gravel over 24" cover)	LF	9,200	5.00	46,000
Drainage Structures				
Northeast Ditch	LS	Job	55,000	55,000
Southeast Ditch	LS	Job	31,000	31,000
Slope Protection				
Settling Basins	SY	6,100	13.00	79,300
Paper Mill Effluent & Flex Board Effluent Catch & Mixing Basins	SY	6,100	13.00	79,300
Collection Basin	SY	1,200	13.00	15,600
East Ditch (Upstream Face)	LS	Job	25,000	25,000
East Ditch (Downstream Face)	LS	Job	50,000	50,000

ALTERNATIVE III: SOIL COVERING WITH VEGETATION

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Drainage				
Dike Drainage (French Drains with filter fabric)	LF	2,000	21.00	42,000
Drainage Ditches	LF	11,000	4.00	44,000
Misc Drainage Structures	LS	Job	10,000	10,000
Hydromulch	AC	70	3,000	210,000
Pond dredging & misc site cleanup (2)	LS	Job	200,000	200,000
Water sprays for dust supressing	Day	125	400	50,000
Sub-Total				$2,774,700
Engineering	LS	Job	120,000	120,000
Construction Management Including chemical analysis of borrowed fill & top soil	LS	Job	400,000	400,000
Sub-Total				$3,294,700
Contingencies (10%)				329,470
TOTAL CAPITAL COST				$3,624,170

2. Estimated Operation & Maintenance Costs:

Groundwater and surface water monitoring (once/year)	$14,000
Labor and material for soil cover and vegetation and roadway maintenance	25,000
Administration and Contingency Costs	10,000
TOTAL OPERATION & MAINTENANCE COST	$49,000

3. Present Worth Analysis:

Present Worth of Capital Cost	$3,624,170
Present Worth of Operation & Maintenance Cost	461,920
TOTAL PRESENT WORTH	$4,086,090

ALTERNATIVE III: SOIL COVERING WITH VEGETATION

(1) Includes temporary fencing, site security, health & safety & environmental monitoring., and decontamination facilities for heavy equipment.

(2) Includes fencing along eastern site boundry, additional signs, beach cleanup a black ditch renovation and monitoring well installation.

ALTERNATIVE III: DEVIATIONS

The operation and maintenance cost of the deviations is estimated to be the same as for the primary alternative. The estimated capital costs of the 24" cover and 30" cover alternatives are as follows:

(i) 24" Cover Alternative

Added construction cost of 6" additional cover soil (50,000 cu.yd. @$6.50/cu yd)	$325,000
Added construction management	40,000
Added contingencies	36,500
Sub-Total	$401,500
Capital cost of the primary alternative	3,624,170
Total Capital Cost	$4,025,670
Present worth of capital cost	4,025,670
Present worth of O & M cost	461,920
TOTAL PRESENT WORTH	$4,487,590

(ii) 30" Cover Alternative

Added construction cost of 12" additional cover soil (100,000 cu.yd. @ 6.50/cu yd)	$650,000
Added construction management	80,000
Added contingencies	73,000
Sub-Total	$803,000
Capital cost of the primary alternative	3,624,170
Total Capital Cost	$4,427,170
Present worth of capital cost	4,427,170
Present worth of O & M cost	461,920
TOTAL PRESENT WORTH	$4,889,090

ALTERNATIVE IV: OFF-SITE LANDFILLING (1)

COST ESTIMATES

1. Estimated Capital Costs:

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Mobilization, setup, & other fixed costs (2)	LS	Job	250,000	250,000
Excavation, loading, transportation & disposal of wet sludges (3)	CY	50,000	5.00	250,000
Excavation, loading, transportation & disposal of waste materials/soil	CY	2,150,000	27.00	58,050,000
Replacement of 57 acres of settling basins				
Clay	CY	185,000	10.00	1,850,000
Soil	CY	180,000	7.00	1,260,000
Seeding	LS	Job	50,000	50,000
Gravel Roads	LS	Job	100,000	100,000
Surface Drains	LS	Job	50,000	50,000
Misc Structures(4)	LS	Job	100,000	100,000
Grading & Placement of Clean fill & top soil on recovered areas	CY	50,000	7.00	350,000
Sub-Total				$62,310,000
Engineering	LS	Job	400,000	400,000
Construction Management	LS	Job	1,440,000	1,440,000
Sub-Total				$64,150,000
Contingency (10%)				6,415,000
TOTAL CAPITAL COST				$70,565,000

ALTERNATIVE IV: OFF-SITE LANDFILLING

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
2. Estimated Operation & Maintenance Costs:				
Groundwater and surface water monitoring around settling basins (once/year)				$10,000
Added Labor, material & off-site disposal costs of waste materials generated at the Waukegan plant and maintenance of settling basins				240,000
Administration and Contingency Costs				50,000
TOTAL OPERATION AND MAINTENANCE COST				$300,000
3. Present Worth Analysis:				
Present worth of Capital Cost				$70,565,000
Present Worth of Operation & Maintenance Cost				2,828,100
TOTAL PRESENT WORTH				$73,393,100

(1) Of entire waste materials and sludges.
(2) Includes temporary fencing, site security, health and safety, environmental monitoring, and decontamination facilities for heavy equipment.
(3) Wet sludge from settling basins.
(4) Includes monitoring wells.

ALTERNATIVE V: ON-SITE LANDFILLING

COST ESTIMATES

1. Estimated Capital Costs:

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Mobilization, setup & other fixed costs (1)	LS	Job	250,000	250,000
Land cost & permits	LS	Job	108,000	108,000
Clearing & grubbing	Acres	50	3,000	150,000
Fill in landfill area	CY	180,000	5.00	900,000
Filter Fabric	SY	225,000	1.40	315,000
Synthetic Membrane Liners	SY	450,000	4.00	1,800,000
Sand & gravel for leachate detection system	CY	80,000	7.00	560,000
Piping for leachate collection/ detection systems	LF	200,000	5.50	1,100,000
Leachate collection/detection manholes	Each	10	1,500	15,000
Excavation & placement of waste materials & sludge	CY	2,200,000	9.60	21,120,000
Transportation & disposal of leachate & runoff	Gal	1,000,000	0.08	80,000
Synthetic Membrane Cap	SY	250,000	4.00	1,000,000
Flow Zone (Sand & Gravel)	CY	90,000	7.00	630,000
Topsoil	CY	90,000	9.00	810,000
Seeding & mulching	SY	270,000	0.60	162,000
Permanent Fencing	LF	6,000	15.00	90,000
Grading & placement of clean fill & top soil on recovered areas	CY	50,000	7.00	350,000
Construction of 57 acres of settling basins & miscellaneous structures as in Alternate IV	LS	Job	3,410,000	3,410,000
Sub-Total				$32,850,000

ALTERNATIVE V: ON-SITE LANDFILLING

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Engineering	LS	Job	600,000	600,000
Construction Management	LS	Job	1,600,000	1,600,000
Sub-Total				$35,050,000
Contingency (10%)				3,505,000
TOTAL ESTIMATED CAPITAL COST				$38,555,000

2. Estimated Annual Operation and Maintenance Costs:

Groundwater & surface water monitoring (once/year)	$28,000
Labor & material for maintenance of vegetation & gravel roads	25,000
Added operation & maintenance cost of disposal of waste materials & process water sludge on the new landfill	15,000
Administration & contingency costs	12,000
TOTAL OPERATION & MAINTENANCE COST	$80,000

3. Present Worth Analysis

Present Worth of Capital Costs	$38,555,000
Present Worth of Operation & Maintenance Cost using a present worth annuity factor of 9.427 for 10% discount rate over 30 years	754,160
TOTAL PRESENT WORTH	$39,309,160

(1) Includes temporary fencing, site security, health and safety, and environmental monitoring.

ALTERNATIVE VI: SOIL COVERING WITHOUT VEGETATION
(Eliminated During Initial Screening)

COST ESTIMATES

1. Estimated Capital Costs:

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Mobilization, setup & other fixed costs (1)	LS	Job	80,000	80,500
Clearing & grubbing	Acre	70	500	35,000
Excavation & Grading				
Balance cut & fill	CY	30,330	6.00	182,000
Extra Fill	CY	21,000	6.00	126,000
Roadways Cover	CY	26,000	7.00	182,000
Cover Soil (21" thick)	CY	175,000	6.50	1,137,500
Top Soil (3" thick)	CY	28,000	9.00	252,000
Gravel Roadways				
Heavy Traffic Roadways (8" gravel over 24" cover)	LF	8,400	20.00	168,000
Light Traffic Raodways (4" gravel over 24" cover)	LF	9,200	5.00	46,000
Drainage Structures				
Northeast Ditch	LS	Job	55,000	55,000
Southeast Ditch	LS	Job	31,000	31,000
Slope Protection				
Settling Basins	SY	6,100	13.00	79,300
Paper Mill Effluent & Flex Board Effluent Catch & Mixing Basins	SY	6,100	13.00	79,300
Collection Basin	SY	1,200	13.00	15,600
East Ditch (Upstream Face)	LS	Job	25,000	25,000
East Ditch (Down Stream Face)	LS	Job	50,000	50,000

ALTERNATIVE VI: SOIL COVERING WITHOUT VEGETATION

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Drainage				
Dike Drainage (French Drains with Filter Fabric)	LF	2,000	21.00	$42,000
Drainage Ditches	LF	11,000	4.00	44,000
Misc Drainage Structures	LS	Job	10,000	10,000
Pond Dredging & misc site cleanup (2)	LS	Job	200,000	200,000
Water Sprays for Dust Supressing	Day	125	400	50,000
Sub-Total				$2,889,700
Engineering	LS	Job	120,000	120,000
Construction Management Including chemical analysis of borrowed fill & top soil	LS	Job	440,000	440,000
Sub-Total				$3,449,700
Contingencies (10%)				344,970
TOTAL CAPITAL COST				$3,794,670

2. Estimated Annual Operation & Maintenance Costs:

Groundwater & surface water monitoring (once/year)	$14,000
Labor & material for soil cover & roadway maintenance	15,000
Administration & Contigency Costs	7,000
TOTAL OPERATION & MAINTENANCE COST	$36,000

3. Present Worth Analysis:

Present Worth of Capital Cost	$3,794,670
Present Worth of Operation & Maintenance Cost	339,370
TOTAL PRESENT WORTH	$4,134,040

(1) Includes temporary fencing, site security, health & safety & environmental monitoring, and decontamination facility for heavy equipment.
(2) Includes fencing along eastern site boundry, additional signs, beach clean up, and black ditch renovation and monitoring well installation.

[illegible] CAPPING
(Eliminated During Initial Screening)

COST ESTIMATES

1. Estimated Capital Costs:

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Mobilization, setup & other fixed costs (1)	LS	Job	100,000	100,000
Clearing & grubbing	Acre	70	500	35,000
Excavation & Grading				
Balanced cut & fill	CY	30,330	6.00	182,000
Extra fill	CY	21,000	6.00	126,000
Roadways Cover	CY	26,000	7.00	182,000
Cover Soil (6" thick) underneath synthetic liner on waste materials	CY	50,000	7.00	350,000
Gravel Roadways				
Heavy traffic roadways (8" gravel over 24" cover)	LF	8,400	20.00	168,000
Light traffic roadways (4" gravel over 24" cover)	LF	9,200	5.00	46,000
Synthetic liner in settling basins and over cover soil	SY	532,000	4.0	2,128,000
Flow Zone Sand	CY	100,000	7.00	700,000
Top Soil (12" thick)	CY	100,000	9.00	900,000
Slope protection				
Settling basins	SY	6,100	13.00	79,300
Paper Mill effluent & Flex Board effluent Catch & Mixing basins	SY	6,100	13.00	79,300
Collection Basin	SY	1,200	13.00	15,600
East Ditch (upstream face)	LS	Job	25,000	25,000
East Ditch (downstream face)	LS	Job	50,000	50,000

ALTERNATIVE VII: CAPPING

Item	Units	Quantity	Unit Cost ($)	Total Cost ($)
Drainage				
Drainage ditches	LF	11,000	4.00	44,000
Misc drainage structures	LS	Job	10,000	10,000
Hydromulch	AC	70	3,000	210,000
Pond dredging & misc site cleanup (2)	LS	Job	200,000	200,000
Water sprays for Dust suppressing	Day	125	400	50,000
Sub-Total				$5,680,200
Engineering	LS	Job	200,000	200,000
Construction Management Including chemical analysis of borrowed fill & top soil	LS	Job	600,000	600,000
Sub-Total				$6,480,200
Contingencies (10%)				648,020
TOTAL CAPITAL COST				$7,128,220

2. Estimated Annual Operation and Maintenance Cost

Groundwater & surface water monitoring (once/year)	$14,000
Labor & material for topsoil, vegetation & roadway maintenance	25,000
Administrative & Contingency costs	10,000
TOTAL OPERATION & MAINTENANCE COST	$49,000

3. Present Worth Analysis:

Present Worth of Capital Cost	$7,128,220
Present Worth of Operation & Maintenance Cost	461,920
TOTAL PRESENT WORK	$7,590,140

(1) Includes temporary fencing, site security, health & safety & environmental monitoring, and decontamination facility for heavy equipment.

(2) Includes fencing along eastern site boundry, additional signs, beach clean, up and black ditch renovation and monitoring well installation.

APPENDIX B

LETTERS CONTAINING FS REPORT REVIEW

COMMENTS AND RESPONSES

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

REPLY TO THE ATTENTION OF:

5HE-12

JUN 11 1986

Marvin Clumpus
Project Coordinator
Manville Service Corporation
P.O. Box 5108
Denver, Colorado 80217

Re: The Johns-Manville Waukegan Disposal Area

Dear Mr. Clumpus:

The U.S. Environmental Protection Agency (U.S. EPA) disapproves the draft Feasibility Study (FS) for the above-mentioned facility. The FS can only be finalized after the U.S. EPA and the Illinois Environmental Protection Agency's (IEPA) questions and comments are addressed appropriately. This letter represents the collective comments of both agencies.

Page 1-1, Second Paragraph:

The statement that on-site air quality does not appear to be affected by releases of asbestos is incorrect. The fact that asbestos concentrations were higher on-site than off-site indicates that there is an impact on air quality.

Page 2-1, Section 2.1.2:

A statement made here implies that there is presently no asbestos being deposited at Johns-Manville (J-M); this contradicts the statement on page 2-5, paragraph one that J-M receives limited quantities of friable asbestos waste.

Page 2-9:

Supply the basis for the statement that this site is perceived as a minimal threat to the environment.

Page 2-11, Section 2.2.1:

Over time, doesn't sludge dry out and release asbestos?

The quantities given on this page do not add up. The paragraph states that 50% of the 175,000 cubic yards of sludge is deposited in a disposal pit and 50,000 cubic yards is deposited in a settling basin. The remaining 37,500 cubic yards should be accounted for.

Page 2-12:

The statement that "fibers longer than 5 microns are the ones generally associated with health risk" is inconsistent with the U.S. EPA's position that asbestos fibers of all lengths present some degree of health risk. The FS report must reflect the Agency's position on this issue.

Page 2-14:

The levels of asbestos in the groundwater and surface water should be reported for fibers of all lengths, not just for those greater than 5 micro

Page 2-15, Second Paragraph:

The statement that "There is no migration of any contaminant from the site" should be amended to read "Based on monitoring data collected during and after the RI, there is no current evidence that contaminants are migrating from the site."

Page 2-16, First Paragraph:

It should also be stated that lead is released from the disposal area to amb air, even though monitoring data have shown that the quantity released is sma

Page 2-17:

If the subsurface soils below the water table were not sampled, what is th basis for the statement that subsurface soil is not a contamination source?

Page 3-1:

The statement that on-site air quality is not impacted by the release of lead or asbestos is incorrect; elevated levels of these contaminants have been detected.

Pages 3-9 and 3-10:

Justification should be provided for the statement that on-site landfilling and on-site stabilization technology are not likely to be accepted by the public.

Pages 3-12 and 5-2:

There is no current evidence to suggest that the inorganic lead found at the J-M Disposal Site is a human or animal carcinogen. The toxic properties of lead should be described.

It is incorrect to state that protection of groundwater is not of concern at the site; therefore, groundwater monitoring is required to ensure that the lead does not migrate. It is also incorrect to state that the lead and asbestos contaminants are encapsulated and in a non-leachable form; elsewhere in the report, it is indicated that there is friable asbestos at the site and that the lead is "not in a readily leachable" form.

Page 4-2, Section 4.1.1.1:

Specify which specific "other inorganic water quality parameters" will be collected and analyzed under the monitoring program.

Page 4-3, Section 4.2.1.3:

Burning of grubbed trees and roots may be better than burying, since the possibility of soil piping after decomposition is thus eliminated.

Page 4-4, Section 4.2.1.3:

IEPA recommends a maximum dike slope of 1:3.

Page 4-4, Section 4.2.1.3 and 4.2.1.4:

The description of grading and drainage near the waste disposal pits needs to be clarified. The report seems to suggest that runoff will be channeled into the disposal pits. It would be more appropriate to reduce infiltration through these areas by directing runoff away from the disposal pits.

Page 4-5, Section 4.2.1.6:

The limestone riprap should be large enough that it does not move (i.e. 8-12" diameter, drop method of placement).

Page 4-5, Third Paragraph:

The plan to test the soils brought to the site for contamination is a good one. Specific criteria for accepting or rejecting the soil can be defined at a later time.

Page 4-6, First Paragraph:

The OSHA standards for asbestos are reported incorrectly in the first paragraph. The numbers are correct, but the units should be fibers per cubic centimeter.

Page 4-6 Section 4.2.1.9:

Trucks coming on-site to deposit fill should be sprayed off on a decontamination pad prior to leaving the site, and wash water should be drained to basins on-site.

Page 4-9, Section 4.4.1.2:

It is recommended that slurry impoundments that are deep, not wide and shallow, be built. Have future electrolysis methods been considered in dewatering of slurry impoundments?

Page 4-13, Section 4.5.1.3:

The leachate collection system should drain into a catch basin, and the leachate detection system should drain into a separate catch basin.

Page 4-13, Section 4.5.1.4:

The shaped surface of the waste material and the sand from on or off-site to be used for the infiltration area should be free of sharp objects which could puncture the synthetic liner.

Page 5-6, Table 5-1:

It is incorrect to list the No Action Alternative as the most favorable alternative for criteria such as operation and maintenance requirements, constructability, time required to implement, and safety to workers and to neighboring facilities and communities.

Page 5-7, First Numbered Item:

Information appears to be missing here; it is not clear why the Clean Water Act is mentioned since it is not included in the subsequent discussion.

Page 5-8, Section 5.2.1.3:

Additional sections of RCRA may be relevant and appropriate (although not legally applicable) to the remedial alternatives that are proposed. These sections would include portions of Subparts G (Closure and Post-Closure) and N (Landfills) of 40 CFR Parts 264 and 265.

Page 5-10, Table 5-2:

The score of "zero" for "OSHA Compliance" for the landfilling alternatives is questionable.

There is no basis for the implication in the table that the most favorable alternative in terms of community requirements is soil covering with vegetation. This can only be stated after the public comment period.

Page 5-14:

The large variations in scores for the various alternatives under "Compliance with Water Quality Requirements During Implementation" are questionable.

Page 5-15:

The statement "There has been no documented increase in the airborne emission of pollutants from the disposal area "is not true. There were elevated asbestos readings.

Page 5-19:

Some of the scores for "Improvements in Biological Environment" are questionable.

Page 6-8, Table 6-2:

The Preliminary Implementation Schedule incorrectly assumes that a final FS will be prepared after the public notice and comment period. The final FS will be submitted before the public comment period. U.S. EPA feels that the schedule is also too lengthy and could be shortened by six months (i.e. construction should be completed by June 30, 1988.)

The U.S. EPA and IEPA concur with J-M that soil covering with vegetation would be the best recommended alternative for the site; however, the agencies do not feel that six inches of soil covering would be adequate. The six inches of soil stand a good chance of eroding away by either wind or water in a relatively short period of time, thereby leaving asbestos material uncovered and releasable to the air. The thickness of the proposed cover is not consistent with recent Office of Solid Waste (OSW) guidance and with most other removal and remedial actions implemented under CERCLA. The OSW guidance recommends a minimum cover thickness of 36 inches for final closure of an asbestos disposal area. This recommendation was based partly on work done by the Army Corps of Engineers (COE) at the Cold Regions Research Laboratory in Hanover, New Hampshire. Research showed that the action of freezing and thawing of the ground can cause an upward migration of pebbles, rocks, and asbestos-containing materials. To prevent freeze-thaw effects, the top of the asbestos layer should be below the depth of freezing in the soil after the cover has been installed. The J-M disposal area is located in an area that has a climate similar to that of New England. Thus, the COE recommendations concerning freeze-thaw effects must be considered.

Based on the factors listed above, the U.S. EPA recommends that at least 36 inches of cover, with vegetation, be applied. Both U.S. EPA and IEPA are concerned with the specifics for the design of the cover (e.g. degree of compaction, soil composition, seeding methods) and have guidance and design criteria documents that provide strong recommendations for the specific design parameters. The agencies would like to discuss cover design criteria with J-M and its contractor at the earliest convenience of all parties. This can be accomplished by either a phone conference or a meeting.

J-M must perform ambient air monitoring on-site during the actual remedial action stage and will be required to monitor the area on frequent occasions thereafter if asbestos materials continue to be disposed of on-site.

If you have any questions regarding these comments, please contact me at (312) 886-4742.

Sincerely yours,

Brad Bradley

Brad Bradley
Remedial Project Manager
Region V CERCLA Enforcement Section

cc: Kurt Neibergall
Federal Site Management Unit
Division of Land Pollution Control
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Manville Sales Corporation
Post Office Box 5108
Denver, Colorado 80217-5108
303 978-2000

Manville

June 23, 1986

CERTIFIED MAIL/RETURN RECEIPT REQUESTED

Mr. Brad Bradley
Remedial Project Manager
U.S. Environmental Protection Agency
Region V
230 South Dearborn Street
Chicago, IL 60604

RE: JOHNS-MANVILLE WAUKEGAN DISPOSAL AREA RI/FS

Dear Mr. Bradley:

This letter is to acknowledge receipt of your comments on Manville's Feasibility Study Report submitted to USEPA on February 7, 1986. Together with our consultant, Kumar Malhotra & Associates ("KMA"), we are in the process of reviewing the comments and preparing a response. However, to fully and fairly respond to all the Agency's comments, we require additional information.

A major comment of the Agency concerns the proper amount of cover for the site. In that regard, the Agency refers to: (1) "recent Office of Solid Waste (OSW) guidance"; (2) "most other removal and remedial actions implemented under CERCLA"; (3) "work done by the Army Corps of Engineers (COE) at the Cold Regions Research Laboratory in Hanover, New Hampshire"; and (4) USEPA and IEPA guidance and design criteria documents with specific requirements or recommendations for design of the cover. Neither Manville nor KMA currently has copies of the referenced materials, nor was specific reference to these materials made in the meetings preceding our submittal of the FS Report. Obviously, without reviewing the documents and materials referenced by the Agency, we cannot properly respond to the Agency's comment.

Therefore, we request copies of the documents and materials referred to in your comments and on which the Agency is relying in suggesting 36 inches of cover. This would include copies of RI/FS Reports and Records of Decision (ROD) for other sites at which the cover requested by the Agency has been incorporated in a selected remedial action alternative implemented under CERCLA. After we have had an opportunity to review these documents and materials, we would be happy to meet with the Agency to discuss cover design criteria and other issues.

We appreciate your efforts in expediting delivery of the requested documents and materials to us.

Very truly yours,

Marvin Clumpus, P.E.
Project Coordinator

MC/jb

cc: Dr. S. K. Malhotra
Kumar Malhotra & Associates, Inc.
Consulting Engineers
3000 East Beltline, NE
Grand Rapids, MI 49505

M
• ENGINEERS • CONSULTANTS • PLANNERS •

3000 East Belt Line N E
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Telephone (616) 361-5092

RECEIVED
SEP 2 1986
U.S. EPA, REGION V
WASTE MANAGEMENT DIVISION
HAZARDOUS WASTE ENFORCEMENT BRANCH

August 25, 1986

Mr. Brad Bradley
Remedial Project Manager (5 HE-12)
USEPA Region V CERCLA Enforcement Section
230 South Dearborn Street
Chicago, Illinois 60604

RE: Johns-Manville Waukegan Disposal Area

Dear Mr. Bradley:

This letter summarizes the responses of Manville to your review comments on the Feasibility Study Report for the Johns-Manville Waukegan Disposal Area. The responses outlined in this letter will be incorporated in the Feasibility Study (FS) Report where applicable. These responses follow the order in which your review comments are presented.

1) Page 1-1, Second Paragraph:

The statement in question will be revised to read as follows:

"On-site and off-site air quality does not appear to be significantly impacted or degraded by release of suspended particulate matter, lead or asbestos fibers.

2) Page 2-1, Section 2.1.2

The revised statements will read as follows:

Page 2-1

"The use of asbestos substitutes and changes in product lines have now eliminated the use of asbestos fiber from the manufacturing process as well as from the manufacturing wastes disposed of at this site."

Page 2-5

"The asbestos disposal pit now receives limited quantities of friable asbestos waste from cleaning/decontamination activities at the Waukegan Plant, and is managed in accordance with the requirements of National Emmission Standards for Hazardous Air Pollutants (NESHAP)."

3) Page 2-9, Section 2.1.9

"The revised statement will read as follows:

"In general this site is perceived as a minimal threat to its environment because of limited potential of exposure of human and wild life (due to site isolation) and of releases of contaminants to the environment (due to encapsulated and relatively bound nature of its contaminants).

4) Page 2-11, Section 2.2.1

Over time, the sludge does dry out but does not appear to release asbestos fibers as the asbestos in the sludge is encapsulated and bound by the lime sludge (predominantly calcium carbonate).

The following sentence will be added to account for the remaining 37,500 cubic yards of sludge.

"The remaining 37,500 ± cubic yards of sludge is deposited on piles of manufacturing wastes."

5) Page 2-12, Section 2.2.5

The statement "Fibers longer than 5 micrometer, the fibers generally associated with health risks" was taken from the final RI report for the site, approved by USEPA in 1985. In addition, it is noted that USEPA's recently proposed RMCL for asbestos in drinking water only applies to medium and long fibers (>10 um in length). None the less, the revised statement will read as follows:

"In terms of fibers longer than 5 micrometers, all concentrations were at or very close to the detection limit (0.003 fibers/ml)."

6) Page 2-14, Section 2.2.6

The observed range of concentrations of fibers of all lengths as well as those of fibers greater than 5 microns in length were reported.

7) Page 2-15, Second Paragraph

The statement will be revised and will read as follows:

"Based on monitoring data collected during and after the RI, there is no evidence that the contaminants are migrating from the site."

8) Page 2-16, First Paragraph

We cannot state that lead is released from the disposal area to ambient air when the Ambient Air Quality Monitoring for Lead and TSP (Technical Memorandum #M-2 September, 1985) showed that observed lead values at on-site monitoring locations were lower than those observed at the off-site monitoring locations, and significantly lower than those observed by Division of Air

Pollution Control, Illinois EPA in the residential and commercial areas of Lake and Cook Counties.

9) Page 2-17, Second Paragraph

Subsurface soils below the water table were sampled and analyzed at the following boring locations and depths. The details are presented in the RI report.

B-1 (31'.5 - 33'.0); B-2 (34'.0 - 35'.5); B-3 (39'.5 - 40'.0);

B-4 (14'.0 - 15'.5); B-5 (20'.0); B-7 (29'.0 - 30'.5);

B-9 (29'.0 - 30'.5) and B-10 (20'.0).

10) Page 3-1, Section 3.1

The revised statement will be read as follows:

"On-site and off-site air quality does not appear to be significantly impacted or degraded by release of suspended particulate matter, lead or asbestos fibers. Some of the on-site air samples contained asbestos fibers at levels somewhat higher than those observed at the off-site locations, but within the range observed in other industrial locations".

11) Pages 3-9 and 3-10

These statements are based on our judgement of the anticipated public reactions due to the adverse environmental impacts associated with on-site landfilling and on-site stabilization remedial alternatives for this site. On-site landfilling will result in air and noise pollution due to moving of large amounts of contaminated material closer to the existing residental dwellings. On-site stabilization will involve processing of surficial soils and hence increase potential of higher levels of airborne contaminants and noise in the vicinity of the site.

12) Pages 3-12 and 5-2

The toxic properties of lead are described in the Endangerment Assessment, Section 5.0 of the RI Report.

The first paragraph on Page 3-12 will be modified to include the suggested sentence as follows:

"Both lead and asbestos fibers can be carcinogenic to human and wildlife population. However, there is no current evidence to suggest that the inorganic lead found at the Johns-Manville Site is a human or animal carcinogen."

The second sentence of the last paragraph on page 3-12 will be modified to read as follows:

"Capping would provide added protection to groundwater (which, however, is not of primary concern at this site)".

The first paragraph on page 5-2 will be modified to read as follows:

"However, groundwater contamination is not expected because the contaminants at this site are not in a readily leachable form."

We agree with you that the groundwater monitoring should be done to insure that on-site lead does not migrate to the groundwater and therefore groundwater monitoring was included in all of the remedial alternatives.

Elsewhere in the report, it is indicated that there is friable asbestos at the site. The friable asbestos is disposed of only in an isolated area of the site. All friable asbestos is bagged prior to its disposal and is covered according to the NESHAP requirements.

13) <u>Page 4-2, Section 4.1.1.1</u>:

The revised statement will read as follows:

"Samples would be analyzed for lead and other inorganic water quality pearameters (pH, SO_4, NO_3-N, chlorides, specific conductance and total alkalinity)"

14) <u>Page 4-3, Section 4.2.1.3</u>:

The revised sentence will read as follows:

"Tree cuttings and stumps would be buried on site in the miscellaneous waste disposal pit or burned on site."

15) <u>Page 4-4, Section 4.2.1.3</u>:

Johns-Manville Disposal Area is not a sanitary landfill. It is a disposal area for the relatively non-combustible and non-biodegradable manufacturing wastes. Some of the existing dikes were constructed many decades ago and are composed of the manufacturing wastes and off specification products such as pipes and shingles and have side slopes greater than 1:1. The majority of the existing dike slopes are between 1:1 and 1:1.5. These are stable and have not shown any sign of abnormal erosion so far.

Decreasing dike slopes to the IEPA recommended standard of 1:3 will require excessive excavation of the consolidated waste materials and will result in adverse noise and air quality environmental impacts as well as increased commitment of monetary and energy resources.

Therefore, the use of dike slopes of 1:2 is appropriate based on the unique site specific conditions at this site.

16) <u>Page 4-4, Sections 4.2.1.3 and 4.2.1.4</u>:

The revised statements will read as follows:

<u>Section 4.2.1.3</u>:

"All top surfaces would slope towards settling basins or to peripheral ditches".

<u>Section 4.2.1.4</u>:

"All surface runoff from the site would flow to process water treatment basins or to the peripheral ditches"

17) <u>Page 4-4, Section 4.2.1.6</u>:

The revised statement will read as follows:

"One layer of 8" - 12" thick lime stone riprap would be placed (by drop method of placement) on portions of interior slopes of settling basin dikes which are susceptable to wind erosion".

18) <u>Page 4-5, Third Paragraph (Section 4.2.1.7)</u>

The following paragraph will be added to the first paragraph of Section 4.2.1.7.

"Specific criteria for accepting or rejecting the soil hauled to the site for use as a cover or fill material will be developed using the background levels of inorganic lead and/or asbestos found in the off-site soil samples. Trucks coming to the site for delivering soil and other materials would be spray washed (on out-side) on a decontamination pad prior to leaving the site and washwater would be drained to settling basins or peripheral ditches for treatment and plant reuse.

19) <u>Page 4-6, First Paragraph</u>:

The units were corrected by a submittal subsequent to submitting the FS report. The last sentence of the first paragraph will read as follows:

"Exposure of any worker would not exceed 8-hr weighted average airbourne asbestos concentration of 2.0* fibers/cubic centimeter and a ceiling concentration of 10 fibers/cubic centimeter for fibers longer than 5.0 micrometers".

*This has since been revised to 0.20 fibers/cubic centimeter.

20) Page 4-6, Section 4.2.1.9:

Your suggestion will be incorporated in Section 4.2.1.7

21) Page 4-9, Section 4.4.1.2:

The first sentence of the last paragraph on Page 4-9 has been revised and will read as follows:

"The sludge periodically removed from the sludge settling basins would be dewatered by using a 2 acre unlined deep sludge drying basin. (This dewatering method was chosen as this has been successfully used at this site for many decades)".

22) Page 4-13, Section 4.5.1.3:

Leachate collection and leachate detection systems as proposed would be separate and drain into separate catch basins.

23) Page 4-13, Section 4.5.1.4:

We agree with you that the sand used should be free from sharp objects to protect the integrity of the synthetic liner. The statement will be revised as follows:

"This membrane would be covered with one foot layer of sand free of sharp objects (taken from the Manville property or an off-site location) to serve as the infiltration flow zone".

24) Page 5-6, Table 5-1:

The scores presented are relative scores in terms of the desirability of different remedial alternatives based on different criteria. No action alternative is the most desirable from O & M requirements, constructability, time of implementation and safety considerations and hence has been given the highest score of 4.0.

25) Page 5-7, First Numbered Item:

The first numbered item will read as follows:

1) CERCLA established NCP for Remedial Action (40 CFR 300)

26) Page 5-8, Section 5.2.1.3:

This paragraph will be revised and read as follows:

"RCRA has specific requirements (40 CFR Part 257) for siting and operating solid waste disposal facilities to minimize adverse effects of disposal facilities on health or the environment (which includes surface water and groundwater). In addition, other sections of RCRA have been considered and where appropriate incorporated in the alternatives. All alternatives comply with the applicable RCRA requirements. However, because of the use of permeable liners the on-site landfilling alternatives should be preferable over the other alternatives".

27) Page 5-10, Table 5-2:

The scores presented are relative scores in terms of the desirability of different remedial alternatives based on different evaluation factors. It is anticipated that the efforts needed to comply with OSHA requirements for landfilling alternatives will be far more extensive than those required for the other remedial alternatives.

The scores presented are based on our evaluations in the absence of public input on the different remedial alternatives. We agree with you that the relative scores for community requirements compliance may change after the public comment period, depending upon the public input.

Landfilling alternatives involve moving of larger quantities of consolidated waste materials and are most likely to result in greater levels of air quality degradation and noise pollution. Therefore, these alternatives are rated unfavorably, similar to the no action alternative, while the soil covering with vegetation alternative is ranked as the most favorable alternative.

28) Page 5-14, Table 5-3:

The scores presented are in whole numbers (0 to 4) and the variations in scores shown was desirable to exhibit the relative desirability of different remedial alternatives.

29) Page 5-15, Section 5.4.1:

The statement will be revised to read as follows:

"There has been no documented discharge of pollutants to surface and/or groundwater from the disposal area. Some of the on-site air samples contained asbestos fibers at levels somewhat higher than those observed at the off-site locations, but within the range observed in other industrial locations".

30) Page 5-19, Table 5-4:

The scores presented are relative scores in terms of desirability of different remedial alternatives for improvements in the biological environment. We believe that the no action alternative is the least desirable and the soil covering with vegetation alternative is the most favorable for improving the biological environment on and around the site.

31) Page 6-8, Table 6-2:

The schedule will be revised to show the submittal of final feasibility study report before the public notice and comment period.

A minimum of two construction seasons are required for clearing and grubbing, grading, soil covering and revegetation of the large waste disposal area, especially when the construction requires soil sampling and analysis, equipment decontamination and health and safety monitoring.

The schedule will be revised as follows:

TENTATIVE DATE	DESCRIPTION OF TASK
September 26, 1986	Submit revised feasibility study report
October, 1986	Public notice for comments
November, 1986	Receive public notice comments
January, 1987	Complete plans and specifications for recommended remedial action alternative
February, 1987	Advertise for bids
April, 1987	Receive bids
April 31, 1987	Award Contract
May, 1987	Start construction
December, 1988	Complete construction

The proposed 9" thick soil cover with vegetation exceeds the NESHAP requirements for active and inactive asbestos waste disposal sites (40 CFR 61 Subpart M) of 6" compacted non-asbestos containing material/soil with vegetation. Therefore, we feel that our recommended alternative is adequate, especially when the emissions of asbestos fibers to the environment from the disposal area and risk to human and wildlife are minimal as concluded in the RI report. Moreover, we have considered the concerns of freeze-thaw effect and believe that the specific conditions at the Waukegan Site are unique and sufficiently different to distinguish it from other sites. However, as noted in Mr. Clumpus's June 23, 1986 letter addressed to you, the issue of proper amount of cover will be discussed further with the Agency after we have a chance to review different documents and materials referenced in your letter.

We do not feel that ambient on-site air monitoring during certain construction activities will provide any timely information to undertake any corrective action. Therefore, we have proposed to monitor the personnel working on-site during site grading activities and wet the construction areas prior to any site grading.

Please feel free to contact me if you have any questions on any of the responses included in this letter.

Sincerely yours,

S. K. Malhotra, Ph.D., P.E.

cc: Marvin Clumpus, P.E.
Project Coordinator
Manville Sales Corporation

SKM:sa

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

OCT - 9 1986

REPLY TO THE ATTENTION OF
5HE-12

Marvin Clumpus
Project Coordinator
Manville Service Corporation
P.O. Box 5108
Denver, Colorado 80217

Re: The Johns-Manville Waukegan Disposal Area

Dear Mr. Clumpus:

This letter is written in response to Kumar Malhotra's August 25, 1986 response letter to the June 11, 1986 U.S. EPA draft Feasibility Study (FS) Report comments. A copy of the August 25, 1986 letter is enclosed, and the comments have been numbered for clarity. Any comment not listed below is acceptable and should be incorporated into the draft FS Report as it appears in the August 25, 1986 letter.

With the exception of the inclusion of the final remedy selected, the FS Report can be considered to be approved by U.S. EPA upon the incorporation of the following comments:

Comment 1): The statement is acceptable as follows: "On-site and off-site air quality does not appear to be significantly impacted or degraded by the release of suspended particulate matter or lead."

Comment 3): This statement should be deleted from the report.

Comment 4): The statement should be amended as follows: "When the sludge dries out, there is a potential to release asbestos to the atmosphere; however, the bound nature of the asbestos in the sludge reduces this potential."

Comment 7): The statement is acceptable and should also be applied in Section 1.1, the second paragraph of page 2-16, and any other time the statement that there is no migration of any of any contaminant from the site is made in the report.

Comment 8): acceptable-Additional Note: On the top of page 2-16, the statement that on-site asbestos releases have not impacted off-site air quality should be deleted from the report; however, since this comment was not made in the first round of comments, U.S. EPA will not disapprove the FS Report if this comment is not addressed.

Comment 9): The statement (last sentence of page 2-17) should be amended to read: "Removal of subsurface soil below the water table will not aid in accomplishing the objectives of the feasibility study."

Comment 10): The statement should be amended to read: "On-site and off-site air quality does not appear to be significantly impacted or degraded by the release of suspended particulate matter or lead. Some of the on-site air samples contained asbestos fibers at levels somewhat higher than those observed at the off-site locations."

Comment 11): acceptable-This statement should be inserted in the report.

Comment 12): All statements made here are acceptable; groundwater monitoring will be discussed at subsequent meetings.

Comment 17): Riprap should be placed on all berms and dikes in the wastewater treatment system, not just those that are susceptible to wind erosion.

Comment 29): The statement is acceptable if the phrase "but within the range observed at other industrial locations" is deleted from the end of the sentence.

Comment 31): The schedule is acceptable. Due to the recent delays in the project, the earlier dates in the schedule must be adjusted; however, construction should still be completed by December 1988.

Since it will be discussed at subsequent meetings, no comment will be provided concerning the appropriate soil cover thickness for the site.

The FS Report should not be printed in final form until the final remedy is included in the report, through the amendment of the report by Johns-Manville and the inclusion of an addendum by U.S. EPA. If you have any questions concerning the contents of this letter, please contact me (312) 886-4742.

Sincerely yours,

Brad Bradley

Brad Bradley, Remedial Project Manager
Region V CERCLA Enforcement Section

Enclosure

cc: Kurt Neibergall
Illinois Environmental Protection Agency

Kumar Malhotra, Kumar Malhotra & Assoc., Inc.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

REPLY TO THE ATTENTION OF

OCT 22 1986

Kumar Malhotra
KMA
3000 East Belt Line N.E.
Grand Rapids, Michigan 49505

Dear Mr. Malhotra:

Enclosed is a copy of the October 9, 1986 letter to Marvin Clumpus presenting U.S. EPA's guidelines for an acceptable remedy for the Johns-Manville-Waukegan, Illinois site. Please use these guidelines when writing the final FS Report.

If you have any questions or comments concerning the enclosed guidelines, please contact me at (312) 886-4742.

Sincerely yours,

Brad Bradley
Brad Bradley, Remedial Project Manager
Region V CERCLA Enforcement Section

Enclosure

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

REPLY TO THE ATTENTION OF

5HE-12

OCT 9 - 1986

Mr. Marvin Clumpus
Project Coordinator
Manville Service Corporation
P.O. Box 5108
Denver, Colorado 80217

Re: The Johns-Manville Waukegan Disposal Area

Dear Mr. Clumpus:

This letter will serve to formalize the guidelines for an acceptable remedy for the Waukegan site presented to Johns-Manville by U.S. EPA at the October 2, 1986 meeting concerning said site. The guidelines, arranged in categories for clarity, are as follows:

North and West Waste Disposal Area Boundaries

The remedy for these areas is acceptable as proposed, with the exception that the cover thickness at the top of the slopes must still be determined.

Wet Areas

Full coverage of all interior slopes with 12-inch thick riprap underlain by four inches of bedding material must be provided.

Dry Areas (This includes the southern waste disposal area boundary)

- The exact cover thickness must still be determined.

- A time limit and provisions for closure of the asbestos disposal pit must be provided, with the stipulation that any asbestos-containing material generated after closure must be deposited off-site in an approved landfill.

- The open area at the northeast corner of the miscellaneous disposal pit must be closed, and the pit must be provided with proper drainage control.

- Written waste handling procedures must be provided for the asbestos disposal pit, the miscellaneous disposal pit, and the sludge disposal pit.

- The remedy proposed for the site roadways is acceptable as outlined in the FS Report.

Miscellaneous Provisions

- As described at the October 2, 1986 meeting, the provisions to clean up the beach and the southwest portion of the waste disposal area must be included in the FS Report.

- If possible, fence must be provided along the eastern site boundary, preferably along the elevated area near the beach.

- As described at the October 2, 1986 meeting, the provision to construct dikes at the depressed areas along the north side of the industrial canal must be included in the FS Report.

- Per the NESHAPS requirement, additional warning signs must be posted along the waste disposal area boundary fences.

Groundwater Monitoring

A detection monitoring system must be provided, including the drilling of additional wells to the north and the east of the site. As a rough guideline, such a monitoring system would consist of approximately four additional wells north of the site and approximately three additional wells slightly west of the existing eastern wells to be monitored for approximately 10 metals, approximately five organics, and all mobility indicator parameters, such as pH.

The only outstanding issue is the appropriate cover thickness for the dry areas, which will be determined through subsequent discussions with Johns-Manville. Any portion of the "soil cover with vegetation" remedy that was not addressed in the above guidelines is acceptable as stated in the draft FS Report.

If you have any questions concerning this letter, please contact me at (312) 886-4742.

Sincerely yours,

Brad Bradley, Remedial Project Manager
Region V CERCLA Enforcement Section

cc: Kurt Neibergall
Federal Site Management Section
Division of Land Pollution Control, IEPA

bcc: N. Niederyang, CES
R. Diefenbach, CES
L. Johnson, 5C-16

If you have any questions concerning this letter, please contact me at (312) 886-4712.

Sincerely yours,

Brad Bradley

Brad Bradley, Remedial Project Manager
Region V SARA Enforcement Section

cc: Kurt Neibergall, E.I.T.
Federal Site Management Unit
Remedial Project Management Section
Division of Land Pollution Control
Illinois Environmental Protection Agency
2200 Churchill Road
Springfield, Illinois 62706

Mr. Kumar Malhotra
Johnson & Malhotra, P.C.
3000 East Belt Line, NE
Grand Rapids, Michigan 49505
616-361-5092
x87315-

19. Page 4-2, Subsection 4.1.1.1 - provide a figure showing the location of the referenced monitoring wells and insert the following sentence in the subsection:"A contingency plan will be developed to take necessary remedial action in the event that contaminant concentrations which would pose a threat to human health and the environment are detected."

20. Page 4-2, Section 4.2, last sentence - insert " and provided with the same cover thickness as the remaining dry disposal areas" after the word "closed."

21. Page 4-4, Subsection 4.2.1.2, last subpoint - add "in order to comply with the requirements of NESHAPS" to the end of the existing sentence and add the following sentence: "The warning signs may be removed after the site is remediated and final closure of the asbestos pit."

22. Page 4-5, First Paragraph - insert the following sentence in the paragraph: The northeast corner of the miscellaneous disposal pit, which is presently open, will be elevated, preventing surface water from exiting said pit."

23. Page 4-5, Subsection 4.2.1.6, first sentence - the beginning should read "One layer of nominal 12" thick limestone riprap with 4" thick bedding material would be..."

24. Page 4-5, Subsection 4.2.1.6, - insert the following sentences in the subsection: "A contingency plan will be implemented to ensure that asbestos-containing sludge is not dredged in the future. This contingency plan will include the discontinuance of dredging activities in the 33-acre settling pond. Any sludge removed from the 33-acre pond in the future will be treated as asbestos-containing waste and will be disposed of accordingly."

25. Page 4-7, Section 4.3, fifth sentence - list the three active waste disposal areas referred to here.

26. Page 4-3, Subsection 4.3.1.1 - insert the following sentence after the first sentence: "Areas in the southwest and northeast corners of the site will also be covered."

27. Page 5-7, Subsection 5.2.1, Last Paragraph, first sentence - the sentence should be amended to read "Local and State governments have requirements that are compatible with those above for specific site conditions."

28. Page 5-9, Subsection 5.2.1.6, first sentence - replace "has been virtually none" with "to date has been minimal."

29. Page 5-12, Subsection 5.3.1, Last Paragraph, first sentence - add "based on limited RI sampling" to the end of the sentence.

30. Page 5-12, Subsection 5.3.1, Last Paragraph, second sentence - add "during RI work" to the end of the sentence.

31. Page 5-12, Subsection 5.3.2, first sentence - the sentence should be amended to read "All relevent air and groundwater standards appear to be met at this site, based on limited RI sampling."

32. Page 5-15, Subsection 5.4.1. first sentence - insert "appear to" after "at this site."

33. Page 6-4, Point 3, First Paragraph, second sentence - delete "and requirements" from the end of the sentence.

34. Page 6-3 - amend the dates in the schedule as follows:

Date listed in document	Amended Date
November 10, 1986	December 4, 1986
November, 1986	January, 1987
December, 1986	February, 1987
January, 1987	February, 1987
February, 1987	March, 1987

35. Appendix A, Page A-1 -include capital costs for the installation of the detection monitoring system in the no action alternative.

Any statements amended by the above comments should be changed anywhere else they appear in the document.

Discussions subsequent to the meeting with J-M held on December 16, 1986 will determine whether U.S. EPA and J-M can agree on the cover thickness required to remediate the site. If U.S. EPA and J-M agree, then J-M shall submit a final FS report to U.S. EPA for review. If U.S. EPA and J-M cannot negotiate an acceptable cover thickness, then J-M shall finalize and submit to U.S. EPA the FS Report with any minor changes required in the draft submitted subsequent to this comment letter, and U.S. EPA shall write an addendum outlining its recommended cover thickness for inclusion in the final FS Report. The following schedule shall be implemented to resolve the conflicts regarding cover thickness remaining after the December 16, 1986 meeting and to provide for the submittal of the final FS Report to U.S. EPA:

Deadline	Event
December 22, 1986	U.S. EPA statement of acceptable cover thickness to J-M
January 5, 1987	Resoultion of remaining cover thickness disputes
January 13, 1987	Submittal of final FS Report to U.S. EPA

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
230 SOUTH DEARBORN ST.
CHICAGO, ILLINOIS 60604

REPLY TO THE ATTENTION OF

5HE-12

DEC 17 1986

Marvin Clumpus
Project Coordinator
Manville Service Corporation
P.O. Box 5108
Denver, Colorado 80217

Re: The Johns-Manville Waukegan Disposal Area

Dear Mr. Clumpus:

The purpose of this letter is to formalize the comments presented to Johns-Manville (J-M) during the November 13, 1986 conference call and to Kumar Malhotra & Associates, Inc. during phone calls on November 20, 1986 and November 24, 1986. A schedule for completion of the Feasibility Study (FS) Report is also provided.

The United States Environmental Protection Agency (U.S. EPA) hereby disapproves the second draft Feasibility Study Report for the above mentioned facility. In order to receive approval for the FS Report, J-M must incorporate the following comments into the document:

1. Second page of document - the non-disclosure statement must be deleted from the document.

2. Page 1-1, Section 1.1, First Paragraph, last sentence - delete the statement "but within the range observed at other industrial locations" from the sentence.

3. Page 1-4, Section 1.5, First Paragraph, Third sentence - replace "is considered acceptable" with "is likely to be acceptable."

4. Page 1-4, Section 1.5 - Add the following statement to this section: "The provisions of the Superfund Amendments and Reauthorization Act of 1986 (SARA) have been considered, and a cover monitoring program, to be mutually agreed upon by U.S. EPA and the Manville Sales Corporation, will be developed to attain the new cleanup standards contained in Section 121 of SARA." This statement should also be inserted in the document at any other point where the recommended alternative is summarized (e.g. Section 2.3.1, second subparagraph; Section 6.2, subpoint 3, etc).

5. Page 2-11, First Paragraph, sixth sentence-replace "contaminants appear to be" with "contaminants were observed to be."

6. Page 2-12, Subsection 2.2.5, Second Paragraph, last sentence - "fibers/ml" should be changed to "fibers/cc."

7. Page 2-12, Subsection 2.2.5, Third Paragraph, second sentence - "Division of the Pollution Control" should be "Division of Air Pollution Control."

8. Page 2-14, Subsection 2.2.5, Third Paragraph, second sentence - "fiber/ml" should be changed to "fibers/ cc."

9. Page 2-15, First Paragraph, first sentence - replace "at the site is of" with "at the site appears to be of."

10. Page 2-15, Third Paragraph, second sentence - "does not threaten" should be "does not appear to threaten."

11. Page 2-15, Subsection 2.2.7, last sentence - "contaminants and absence of" should be "contaminants and apparent absence of."

12. Page 2-15, First Paragraph, last sentence - add "based on limited data collected during the RI" to the end of the sentence.

13. Page 2-17, Second Subparagraph, second sentence - the end of the sentence should read "under existing alkaline conditions and the bound nature of lead in the waste materials."

14. Page 2-17, Third Subparagraph - the beginning should read "Sub-surface soil below the water table is not perceived to be a contamination source based on limited RI sampling, and its removal below..."

15. Page 3-12, Subsection 3.4.1, Second Paragraph, first sentence - replace "of the site is not contaminated by lead" with "of the site appears not to be contaminated by lead."

16. Page 4-2, first complete sentence - replace "assure that" with "detect whether."

17. Page 4-2, Subsection 4.1.1.1, first sentence - the parenthetical statement should be amended to read "such as pH, SO_4, NO_3-N, Cr, Al, Cl, specific conductance, total alkalinity, pentachlorophenol, and volatile organic compounds indicated by U.S. EPA scans 601 and 602."

18. Page 4-2, Subsection 4.1.1.1, last sentence - the first parenthetical statement should read "3 north of the site, 3 east of eastern site boundary, two of which will be two well clusters, one west and one south of the site."

APPENDIX C

UPFREEZING COVER THICKNESS ANALYSIS

BY

GOLDER ASSOCIATES

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

November 6, 1986 Our ref: 863-2041

Manville Service Corporation
12999 Deer Creek Canyon Road
Mail Stop 3-25
Littleton, Colorado 80127

ATTENTION: Mr. Marvin Clumpus, P.E., Senior Engineer

RE: UPFREEZING COVER THICKNESS ANALYSIS -- TO THREE FEET -- PRELIMINARY ESTIMATES FOR THE WAUKEGAN, ILLINOIS PLANT WASTE DISPOSAL AREA

Dear Mr. Clumpus:

The attached UPFREEZ5 computer output extends the cover thicknesses (TCT) analyzed to 3.0 ft and also extends the extremes in F to 0.5 for S to 50%. These results can be used to examine the implications of cover in excess of 2.0 ft and also effects of extreme and very extreme values of F and S.

The conditions and assumptions are identical to the UPFREEZ5 output transmitted to you on October 27, 1986. You will note that extending TCT to 3.0 ft required modification to the output format of UPFREEZ5 because upfreeze estimates were too large to fit across the page. These output format modifications are contained in UPFREEZ5X. Calculation procedures and assumptions are all unchanged.

As in our October 27 transmittal, these preliminary estimates are for upfreezing of objects less than about four or five inches in size ($X - A \leq 0.3$ ft) initially located at the bottom of the H1=TCT-ft cover (i.e., at the top of the waste pile). We understand this size of object is considered the critical size for upfreezing by EPA's consultant Mr. Richard McGaw, P.E.

These preliminary estimates make the assumptions shown on the program UPFREEZE5X computer output. Variables, symbols and their relation to object upfreezing are defined using the upfreezing equation (Eq. 1) in Table 1.

GOLDER ASSOCIATES, INC. • 4104-148TH AVENUE N.E., REDMOND (SEATTLE), WASHINGTON 98052 U.S.A. • TELEPHONE (206) 883-0777 • TELEX 5108002944

OFFICES IN CANADA • UNITED STATES • UNITED KINGDOM • AUSTRALIA

Preliminary estimates shown on the attached UPFREEZ5X output indicate the following for cover thickness of 1.5 ft to 3.0 ft.

- A moderate-heaving, moderate-stability cover (S=10%, F=0.1) provides lower bound [i.e., LBOND or UP.YRS*(1 - CV)] upfreezing protection of:

  - 518 years for 1.5 ft of cover
  - 808 years for 2.0 ft of cover
  - 1,399 years for 2.5 ft of cover
  - 2,749 years for 3.0 ft of cover

  R50 (50-year reliability) is 100% in each case.

- For extreme conditions of high-heaving and poor-stability (S=30%, F=0.3) lower bound (LBOND) estimates are:

  - 71 years for 1.5 ft of cover
  - 154 years for 2.0 ft of cover
  - 427 years for 2.5 ft of cover
  - 1,881 years for 3.0 ft of cover

  R50 (50-year reliability) is 100% in each case.

- Sensitivity to values of S and F beyond expected extremes shows R50 (50-year reliability) estimates:

  - For a 1.5 ft cover R50 is or exceeds 90% for all $S \leq 50\%$ and $F \leq 0.3$ or for all $F \leq 0.4$ and $S \leq 30\%$.

  - For a 2.0 ft cover R50 is or exceeds 99% for all $S \leq 50\%$ and $F \leq 0.5$.

  - For a 2.5 ft cover the R50 is 100% for all $S \leq 50\%$ and $F \leq 0.5$.

Please call if you need any clarification, elaboration or further discussion.

Sincerely,

GOLDER ASSOCIATES

Charles L. Vita

Charles L. Vita, P.E.
Senior Project Manager

DMCC/CLV/111

Attachment

Table 1

Upfreezing Equation (Eq. 1) and UPFREEZ5 Output

$$U = (X - A - T) * S * F * C$$

U = Upfreezing distance of buried object. In program UPFREEZ5 U is the cover increment (0.1 ft) for DELTA and H1=TCT for UP.YRS for total cover thickness TCT.

X = Projected length of buried object.

Note all projected lengths are perpendicular to the freezing front--i.e., vertical for flat ground and for sloping ground inclined from vertical toward horizontal by the slope angle of the ground.

A = Projected length of buried object required for adfreeze to overcome anchorage before uplifting can occur.

T = Projected length of buried object below maximum depth of freezing front. T is a function of object depth below top of cover. T and C are functionally related.

Note (X - A - T) is the effective portion of the object over which frost heaving can cause upfreezing. (X - A) is called EPS.UF in program UPFEEZE5.

S = Average heave strain over the distance (X - A - T).

F = Heave fraction not recovered on thawing.

C = Effective number of complete freeze thaw cycles over the distance (X - A - T). C is modeled as a random variable to reflect the uncertainty in future yearly thermal loads (freeze indexes, FI) and thermal capacity of the waste pile and cover soil (to maintain frost out of the waste pile or maximize T). Thermal loads are modeled using a lognormal distribution based on a conservative interpretation of 1949-85 Waukegan FI estimates. Thermal capacity (TC) is modeled using the modified Berggren equation and thermal geotechnical assumptions, as stated on the program UPFREEZ5 output. In UPFREEZ5 C is estimated as FP (probability of having frost to the depth H1 in any year) and FPY (return period for a frost table at H1). Results are displayed as averages (AVG) ± a coefficient of variation (CV%).

Program UPFREEZ5: 1. Searches for (X - A - T)*C which maximizes U for given S and F, subject to (X-A)<EPS.UF. Maximum (X-A) is displayed as H3M. 2. Calculates average years to upfreeze through an increment (set=0.1 ft) of cover, DELTA, estimated as [0.1/(X-A-T)*C*F*S]. 3. Calculates average years to upfreeze the object, UP.YRS, as the sum of DELTA for H1 from 0.1 to the total cover thickness, TCT. A minus one standard deviation estimate, LBOND, an absolute lower bound, ABOND, and the estimated reliability that upfreezing through the cover will take 50 years or more, R50, are also calculated and displayed.

A more refined estimate for years of protection against upfreezing for a cover of thickness TCT is UP.YRS for H1=TCT using cover thermal properties plus the difference in DELTA for H1=TCT between UP.YRS for the cover thermal properties in H3 and UP.YRS for waste pile properties in H3.

All estimates are conditional on S and F, and EPS.UF.

```
**************************************  PROGRAM UPFREEZ5X  **********************************
SAVED UNDER FILE NAME: UPF1-5X                                  DATE: 10-31-1986
                                                                 TIME: 17:04:13

                    PROBABILISTIC GEOTECHNICAL THERMAL ANALYSIS
                         1-LAYER FINE-GRAINED COVER SYSTEM

                    MODIFIED BERGGREN EQUATION WITH KERSTEN K'S

                               PROPERTIES OF COVER

COVER LAYER DRY DENSITY=100 PCF,  WATER CONTENT =20.3% (80% SAT)     100% S=25.4%
AVERAGE HEAVE STRAIN = 10% TO 50%
FRACTION OF HEAVE NOT RECOVERED ON THAWING (R) = 0.10 TO 0.30
LAMBDA*SQR[N-FACTOR]: AVG=0.70;  SD=0.10
(COVER AND WASTE PILE USE THE SAME VALUES)


                             PROPERTIES OF WASTE PILE

FINE-GRAINED SOIL
UNFROZEN DRY DENSITY = 100. [PCF], WATER CONTENT = 20%. (80% SAT)     100% S=25.4%
AVERAGE HEAVE STRAIN = 10% TO 50%
FRACTION OF HEAVE NOT RECOVERED ON THAWING (R) = 0.10 TO 0.50

                              THERMAL LOAD INFORMATION

FREEZE INDEX (FI) FOR WAUKEKGAN ASSUMED LOGNORMAL WITH MEAN & STANDARD DEVIATIO
FROM HISTORICAL DATA 1949-50 TO 1984-85 EXCEPT 1982-83 (TOTAL = 25 YEARS)
LOGNORMAL FREEZE INDEX (THERMAL LOAD): MEAN=848, MEDIAN=800, SD=320, CV=0.378,
          SD[LN FI]=0.365, SKEWNESS=1.277                                HOWEVER:
CONSERVATIVE LOGNORMAL ENVELOPE USED FOR FREEZE INDEX: MEDIAN = 875, MEAN = 935
                                                       SD[LN FI] =0.365
ALL YEARS HAVE HISTORICAL FI FREQUENCY <= FORCASTED (PREDICTED) PROBABILITIES
 (1983-84 [FI=1200] LIES ON THE ENVELOPE ALL OTHER YEARS ARE BELOW)


OBJECT UPFREEZING INFORMATION--EQUATION:    U = (X - A - T) * S * R * C

UPFREEZING ASSUMPTIONS:
EFFECTIVE PARTICLE SIZE (X - A) IS EPS.UF = 0.30 FT
AVERAGE HEAVE STRAIN (S) = 10 %  TO 50 %
FRACTION OF HEAVE NOT RECOVERED ON THAWING (R) = 0.10 TO 0.30
EFFECTIVE NUMBER OF COMPLETE FREEZE THAW CYCLES (C) = NUMBER OF FREEZE SEASONS
                                                       (YEARS) * P.H3
*NOTE:  BOTH C AND P.H3 ARE DEPTH DEPENDENT
```

S=10% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF, WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 10%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE	
					--------- YEARS			----------		%	YEARS	FT	YEARS	FT
H1	TC(AVG&CV)		FP(AVG&CV)		FPY	UP.YRS	CV	LBOND	ABOND	R50	DELTA	H3M	DELTA	H3M
1.00	186	38%	.9998	0%	1	334	0%	334	333	100	34	0.3	34	0.3
1.10	225	38%	.9983	0%	1	368	0%	368	367	100	34	0.3	34	0.3
1.20	268	36%	.9953	0%	1	403	0%	403	400	100	36	0.3	35	0.3
1.30	315	38%	.9861	1%	1	439	0%	439	433	100	38	0.3	37	0.3
1.40	365	38%	.9670	3%	1	478	0%	477	467	100	41	0.3	41	0.3
1.50	419	38%	.9351	7%	1	522	1%	518	500	100	46	0.3	46	0.3
1.60	477	38%	.8898	12%	1	572	2%	563	533	100	54	0.3	53	0.3
1.70	539	38%	.8337	19%	1	631	3%	613	567	100	66	0.3	65	0.3
1.80	604	38%	.7711	28%	1	706	5%	669	600	100	84	0.3	83	0.3
1.90	673	38%	.7067	39%	2	804	9%	734	633	100	112	0.3	111	0.3
2.00	745	38%	.6440	49%	2	938	14%	808	667	100	157	0.3	155	0.3
2.10	822	38%	.5847	59%	3	1130	21%	894	700	100	228	0.3	225	0.3
2.20	902	38%	.5289	69%	4	1415	30%	994	733	100	343	0.3	339	0.3
2.30	986	38%	.4759	76%	5	1850	40%	1110	767	100	526	0.2	523	0.2
2.40	1073	38%	.4250	83%	7	2523	51%	1244	800	100	820	0.2	815	0.2
2.50	1165	38%	.3755	87%	11	3589	61%	1399	833	100	1312	0.2	1304	0.2
2.60	1260	38%	.3276	91%	18	5319	70%	1579	867	100	2148	0.2	2134	0.2
2.70	1358	38%	.2816	94%	28	8186	78%	1793	900	100	3585	0.2	3563	0.2
2.80	1461	38%	.2383	95%	47	13022	84%	2050	933	100	6086	0.2	6047	0.2
2.90	1567	38%	.1984	97%	78	21304	89%	2362	967	100	10479	0.2	10412	0.2
3.00	1677	38%	.1625	98%	133	35677	92%	2749	1000	100	18266	0.2	18151	0.2
3.10	1791	38%	.1310	98%	229	60901	95%	3233	1033	100	32182	0.2	31981	0.2

S=10% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF, WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF WATER CONT.= 29.7% C/L=.0085 L=3658 KF=1.15

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 10%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.80

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT H1	F-DEG*DAYS TC(AVG&CV)		PROB. FP(AVG&CV)		COVER THERMAL PROPERTIES IN H3 (R1.3=1) YEARS FPY	UP.YRS	CV	LBOND	ABOND	% R50	YEARS DELTA	FT H3M	WASTEPILE YEARS DELTA	FT H3M
1.00	186	38%	.9998	0%	1	167	0%	167	167	100	17	0.3	17	0.3
1.10	225	38%	.9988	0%	1	184	0%	184	183	100	17	0.3	17	0.3
1.20	268	38%	.9953	0%	1	201	0%	201	200	100	18	0.3	18	0.3
1.30	315	38%	.9861	1%	1	220	0%	219	217	100	19	0.3	19	0.3
1.40	365	38%	.9670	3%	1	239	0%	239	233	100	20	0.3	20	0.3
1.50	419	38%	.9351	7%	1	261	1%	259	250	100	23	0.3	23	0.3
1.60	477	38%	.8898	12%	1	286	2%	281	267	100	27	0.3	27	0.3
1.70	539	38%	.8337	19%	1	316	3%	306	283	100	33	0.3	32	0.3
1.80	604	38%	.7711	28%	1	353	5%	335	300	100	42	0.3	41	0.3
1.90	673	38%	.7067	39%	2	402	9%	367	317	100	56	0.3	55	0.3
2.00	745	38%	.6440	49%	2	469	14%	404	333	100	78	0.3	77	0.3
2.10	822	38%	.5847	59%	3	565	21%	447	350	100	114	0.3	112	0.3
2.20	902	38%	.5289	69%	4	708	30%	497	367	100	171	0.3	169	0.3
2.30	986	38%	.4759	76%	5	925	40%	555	383	100	263	0.2	262	0.2
2.40	1073	38%	.4250	83%	7	1262	51%	622	400	100	410	0.2	408	0.2
2.50	1165	38%	.3755	87%	11	1795	61%	699	417	100	656	0.2	652	0.2
2.60	1260	38%	.3276	91%	18	2660	70%	790	433	100	1074	0.2	1067	0.2
2.70	1358	38%	.2816	94%	28	4093	78%	897	450	100	1793	0.2	1781	0.2
2.80	1461	38%	.2383	95%	47	6511	84%	1025	467	100	3043	0.2	3023	0.2
2.90	1567	38%	.1984	97%	78	10652	89%	1181	483	100	5239	0.2	5206	0.2
3.00	1677	38%	.1625	98%	133	17838	92%	1374	500	100	9133	0.2	9076	0.2
3.10	1791	38%	.1310	98%	229	30450	95%	1617	517	100	16091	0.2	15991	0.2

S=10% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

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H1  = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)           KU=0.81
      FROZEN DRY DENS. =  90 PCF, WATER CONT.= 29.7% C/L=.0085  L=3653  KF=1.15
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3  = WASE PILE OF SOIL--HAVING:
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)           KU=0.81
      FROZEN DRY DENS. =  90 PCF  WATER CONT.= 29.7% C/L=.0085  L=3653  KF=1.15

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 10%,          95% OF MAX L
   HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
   LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY    = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROFS IN H3) BUT
         CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
         CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT:  UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
             LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
             ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
             R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS
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FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE	
					---------- YEARS ----------					%	YEARS	FT	YEARS	FT
H1	TC(AVG&CV)		FP(AVG&CV)		FPY	UP.YRS	CV	LBOND	ABOND	R50	DELTA	H3M	DELTA	H3M
1.00	186	38%	.9998	0%	1	111	0%	111	111	100	11	0.3	11	0.3
1.10	225	38%	.9988	0%	1	123	0%	123	122	100	11	0.3	11	0.3
1.20	268	38%	.9953	0%	1	134	0%	134	133	100	12	0.3	12	0.3
1.30	315	38%	.9861	1%	1	146	0%	146	144	100	13	0.3	12	0.3
1.40	365	38%	.9670	3%	1	159	0%	159	156	100	14	0.3	14	0.3
1.50	419	38%	.9351	7%	1	174	1%	173	167	100	15	0.3	15	0.3
1.60	477	38%	.8898	12%	1	191	2%	189	178	100	18	0.3	18	0.3
1.70	539	38%	.8337	19%	1	210	3%	204	189	100	22	0.3	22	0.3
1.80	604	38%	.7711	28%	1	235	5%	223	200	100	28	0.3	28	0.3
1.90	673	38%	.7067	39%	2	268	9%	245	211	100	37	0.3	37	0.3
2.00	745	38%	.6440	49%	2	313	14%	269	222	100	52	0.3	52	0.3
2.10	822	38%	.5847	59%	3	377	21%	298	233	100	76	0.3	75	0.3
2.20	902	38%	.5289	69%	4	472	30%	331	244	100	114	0.3	113	0.3
2.30	986	38%	.4759	76%	5	617	40%	370	256	100	175	0.2	174	0.2
2.40	1073	38%	.4250	83%	7	841	51%	415	267	100	273	0.2	272	0.2
2.50	1165	38%	.3755	87%	11	1196	61%	466	278	100	437	0.2	435	0.2
2.60	1260	38%	.3276	91%	18	1773	70%	526	289	100	716	0.2	711	0.2
2.70	1358	38%	.2816	94%	28	2729	78%	598	300	100	1195	0.2	1188	0.2
2.80	1461	38%	.2383	95%	47	4341	84%	683	311	100	2029	0.2	2016	0.2
2.90	1567	38%	.1984	97%	78	7101	89%	787	322	100	3493	0.2	3471	0.2
3.00	1677	38%	.1625	98%	133	11892	92%	916	333	100	6089	0.2	6050	0.2
3.10	1791	38%	.1310	98%	229	20300	95%	1078	344	100	10727	0.2	10661	0.2

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

```
H1  = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)              KU=0.81
      FROZEN DRY DENS. =  90 PCF, WATER CONT.= 29.7% C/L=.0085  L=3658  KF=1.15
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3  = WASE PILE OF SOIL--HAVING:
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)              KU=0.81
      FROZEN DRY DENS. =  90 PCF  WATER CONT.= 29.7% C/L=.0085  L=3658  KF=1.15
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BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 10%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

```
FPY    = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
         CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
         CONSERATIVE FOR ALL OBJECTS HAVING (X-A) <  0.30 FT
FOR H1=TCT:  UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
             LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
             ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
             R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS
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FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE	
					--------- YEARS	----------				%	YEARS	FT	YEARS	FT
H1	TC(AVG&CV)		FP(AVG&CV)		FPY	UP.YRS	CV	LBOND	ABOND	R50	DELTA	H3M	DELTA	H3M
1.00	186	38%	.9998	0%	1	83	0%	83	83	100	8	0.3	8	0.3
1.10	225	38%	.9988	0%	1	92	0%	92	92	100	9	0.3	9	0.3
1.20	268	38%	.9953	0%	1	101	0%	101	100	100	9	0.3	9	0.3
1.30	315	38%	.9861	1%	1	110	0%	110	108	100	9	0.3	9	0.3
1.40	365	38%	.9670	3%	1	120	0%	119	117	100	10	0.3	10	0.3
1.50	419	38%	.9351	7%	1	130	1%	130	125	100	11	0.3	11	0.3
1.60	477	38%	.8898	12%	1	143	2%	141	133	100	13	0.3	13	0.3
1.70	539	38%	.8337	19%	1	158	3%	153	142	100	16	0.3	16	0.3
1.80	604	38%	.7711	28%	1	176	5%	167	150	100	21	0.3	21	0.3
1.90	673	38%	.7067	39%	2	201	9%	183	158	100	28	0.3	28	0.3
2.00	745	38%	.6440	49%	2	234	14%	202	167	100	39	0.3	39	0.3
2.10	822	38%	.5847	59%	3	282	21%	223	175	100	57	0.3	56	0.3
2.20	902	38%	.5289	69%	4	354	30%	249	183	100	86	0.3	85	0.3
2.30	986	38%	.4759	76%	5	462	40%	278	192	100	132	0.2	131	0.2
2.40	1073	38%	.4250	83%	7	631	51%	311	200	100	205	0.2	204	0.2
2.50	1165	38%	.3755	87%	11	897	61%	350	208	100	328	0.2	326	0.2
2.60	1260	38%	.3276	91%	18	1330	70%	395	217	100	537	0.2	534	0.2
2.70	1358	38%	.2816	94%	28	2047	78%	448	225	100	896	0.2	891	0.2
2.80	1461	38%	.2383	95%	47	3255	84%	512	233	100	1521	0.2	1512	0.2
2.90	1567	38%	.1984	97%	78	5326	89%	591	242	100	2620	0.2	2603	0.2
3.00	1677	38%	.1625	98%	133	8919	92%	687	250	100	4567	0.2	4538	0.2
3.10	1791	38%	.1310	98%	229	15225	95%	808	258	100	8046	0.2	7995	0.2

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5 -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF, WATER CONT.= 29.7% C/L=.0085 L=3653 KF=1.15
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 90 PCF WATER CONT.= 29.7% C/L=.0085 L=3653 KF=1.15

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 10%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA×SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT H1	F-DEG×DAYS TC(AVG&CV)		PROB. FP(AVG&CV)		COVER THERMAL PROPERTIES IN H3 (R1.3=1) FPY	YEARS UP.YRS	CV	LBOND	ABOND	% R50	YEARS DELTA	FT H3M	WASTEPILE YEARS DELTA	FT H3M
1.00	156	38%	.9998	0%	1	67	0%	67	67	100	7	0.3	7	0.3
1.10	225	38%	.9985	0%	1	74	0%	74	73	100	7	0.3	7	0.3
1.20	268	38%	.9953	0%	1	81	0%	81	80	100	7	0.3	7	0.3
1.30	315	38%	.9861	1%	1	88	0%	88	87	100	8	0.3	7	0.3
1.40	365	38%	.9670	3%	1	96	0%	95	93	100	8	0.3	8	0.3
1.50	419	38%	.9351	7%	1	104	1%	104	100	100	9	0.3	9	0.3
1.60	477	38%	.8898	12%	1	114	2%	113	107	100	11	0.3	11	0.3
1.70	539	38%	.8337	19%	1	126	3%	123	113	100	13	0.3	13	0.3
1.80	604	38%	.7711	28%	1	141	5%	134	120	100	17	0.3	17	0.3
1.90	673	38%	.7067	39%	2	161	9%	147	127	100	22	0.3	22	0.3
2.00	745	38%	.6440	49%	2	188	14%	162	133	100	31	0.3	31	0.3
2.10	822	38%	.5847	59%	3	226	21%	179	140	100	46	0.3	45	0.3
2.20	982	38%	.5289	69%	4	283	30%	199	147	100	69	0.3	68	0.3
2.30	986	38%	.4759	76%	5	370	40%	222	153	100	105	0.2	105	0.2
2.40	1073	38%	.4250	83%	7	505	51%	249	160	100	164	0.2	163	0.2
2.50	1165	38%	.3755	87%	11	718	61%	280	167	100	262	0.2	261	0.2
2.60	1260	38%	.3276	91%	18	1064	70%	316	173	100	430	0.2	427	0.2
2.70	1358	38%	.2816	94%	28	1637	78%	359	180	100	717	0.2	713	0.2
2.80	1461	38%	.2383	95%	47	2604	84%	410	187	100	1217	0.2	1209	0.2
2.90	1567	38%	.1984	97%	78	4261	89%	472	193	100	2096	0.2	2082	0.2
3.00	1677	38%	.1625	98%	133	7135	92%	550	200	100	3653	0.2	3630	0.2
3.10	1791	38%	.1310	98%	229	12180	95%	647	207	100	6436	0.2	6396	0.2

S=20% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 80 PCF, WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.10
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 80 PCF WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.16

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 20%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
LAMBDA*SORIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERVATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS	------------				%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	244	38	.998	0.22	1	168	0.02	168	167	100	18	.3	18
1.1	295	38	.991	0.91	1	186	0.07	186	183	100	19	.3	19
1.2	351	38	.974	2.71	1	206	0.25	205	200	100	21	.3	21
1.3	412	38	.940	6.31	1	228	0.67	226	217	100	24	.3	24
1.4	477	38	.890	12.25	1	254	1.60	250	233	100	29	.3	29
1.5	548	38	.825	20.70	1	288	3.38	278	250	100	37	.3	37
1.6	624	38	.752	31.29	1	332	6.51	310	267	100	51	.3	51
1.7	704	38	.679	43.16	2	395	11.56	349	283	100	74	.3	73
1.8	789	38	.609	55.15	2	488	19.02	395	300	100	113	.2	112
1.9	879	38	.544	66.14	3	632	28.73	450	317	100	174	.2	172
2.0	974	38	.483	75.37	5	858	40.10	514	333	100	279	.2	277
2.1	1074	38	.425	82.60	7	1231	52.14	589	350	100	466	.2	462
2.2	1179	38	.368	87.96	12	1866	63.67	678	367	100	805	.2	798
2.3	1288	38	.314	91.77	20	2984	73.68	785	383	100	1430	.2	1418
2.4	1403	38	.262	94.41	35	4999	81.66	917	400	100	2600	.2	2579
2.5	1522	38	.215	96.21	63	8710	87.59	1081	417	100	4822	.2	4782
2.6	1646	38	.172	97.43	115	15666	91.77	1289	433	100	9091	.2	9016
2.7	1776	38	.135	98.25	213	28901	94.61	1558	450	100	17379	.2	17238
2.8	1909	38	.104	98.80	403	54397	96.48	1913	467	100	33614	.2	33345
2.9	2048	38	.078	99.17	773	104035	97.70	2388	483	100	65661	.2	65145
3.0	2192	38	.058	99.42	1499	201527	98.49	3034	500	100	129323	.2	128327

S=20% F=0.20

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 80 PCF, WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.18
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 80 PCF WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.18

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 20%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SORIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
FT	F-DEG*DAYS		PROB.		------- YEARS -------					%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
.0	244	38	.998	0.22	1	84	0.02	84	83	100	9	.3	9
1.1	295	38	.991	0.91	1	93	0.07	93	92	100	9	.3	9
1.2	351	38	.974	2.71	1	103	0.25	103	100	100	10	.3	10
1.3	412	38	.940	6.31	1	114	0.67	113	108	100	12	.3	12
1.4	477	38	.890	12.25	1	127	1.60	125	117	100	15	.3	14
1.5	548	38	.825	20.70	1	144	3.38	139	125	100	19	.3	18
1.6	624	38	.752	31.29	1	166	6.51	155	133	100	26	.3	25
1.7	704	38	.679	43.16	2	197	11.56	175	142	100	37	.3	37
1.8	789	38	.609	55.15	2	244	19.02	198	150	100	57	.2	56
1.9	879	38	.544	66.14	3	316	28.73	225	158	100	87	.2	86
2.0	974	38	.483	75.37	5	429	40.10	257	167	100	139	.2	138
2.1	1074	38	.425	82.60	7	615	52.14	294	175	100	233	.2	231
2.2	1179	38	.368	87.96	12	933	63.67	339	183	100	403	.2	399
2.3	1289	38	.314	91.77	20	1492	73.68	393	192	100	715	.2	709
2.4	1403	38	.262	94.41	35	2499	81.66	458	200	100	1300	.2	1289
2.5	1522	38	.215	96.21	63	4355	87.59	540	208	100	2411	.2	2391
2.6	1646	38	.172	97.43	115	7833	91.77	644	217	100	4545	.2	4508
2.7	1776	38	.135	98.25	213	14450	94.61	779	225	100	8689	.2	8619
2.8	1909	38	.104	98.80	403	27199	96.48	956	233	100	16807	.2	16673
2.9	2048	38	.078	99.17	773	52017	97.70	1194	242	100	32830	.2	32572
3.0	2192	38	.058	99.42	1499	100763	98.49	1517	250	100	64662	.2	64164

S=20% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 675 MEAN = 935 SD.LN=.365

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H1  = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)          KU=0.81
      FROZEN DRY DENS. =  80 PCF, WATER CONT.= 37.7% C/L=.0076  L=4124  KF=1.18
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3  = WASE PILE OF SOIL--HAVING:
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)          KU=0.81
      FROZEN DRY DENS. =  80 PCF  WATER CONT.= 37.7% C/L=.0076  L=4124  KF=1.18

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 20%,          95% OF MAX L
   HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
   LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY    = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
         CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
         CONSERATIVE FOR ALL OBJECTS HAVING (X-A) <  0.30 FT
FOR H1=TCT:  UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
             LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
       ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
             R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS
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FT	F-DEG×DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					---------- YEARS			-------------		%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	244	38	.998	0.22	1	56	0.02	56	56	100	6	.3	6
1.1	295	38	.991	0.91	1	62	0.07	62	61	100	6	.3	6
1.2	351	38	.974	2.71	1	69	0.25	68	67	100	7	.3	7
1.3	412	38	.940	6.31	1	76	0.67	75	72	100	8	.3	8
1.4	477	38	.890	12.25	1	85	1.60	83	78	100	10	.3	10
1.5	548	38	.825	20.70	1	96	3.38	93	83	100	12	.3	12
1.6	624	38	.752	31.29	1	111	6.51	103	89	100	17	.3	17
1.7	704	38	.679	43.16	2	132	11.56	116	94	100	25	.3	24
1.8	789	38	.609	55.15	2	163	19.02	132	100	100	38	.2	37
1.9	879	38	.544	66.14	3	211	28.73	150	106	100	58	.2	57
2.0	974	38	.463	75.37	5	286	40.10	171	111	100	93	.2	92
2.1	1074	38	.425	82.60	7	410	52.14	196	117	100	155	.2	154
2.2	1179	38	.368	87.96	12	622	63.67	226	122	100	268	.2	266
2.3	1288	38	.314	91.77	20	995	73.68	262	128	100	477	.2	473
2.4	1403	38	.262	94.41	35	1666	81.66	306	133	100	867	.2	860
2.5	1522	38	.215	96.21	63	2903	87.59	360	139	100	1607	.2	1594
2.6	1646	38	.172	97.43	115	5222	91.77	430	144	100	3030	.2	3005
2.7	1776	38	.135	98.25	213	9634	94.61	519	150	100	5793	.2	5746
2.8	1909	38	.104	98.80	403	18132	96.48	638	156	100	11205	.2	11115
2.9	2048	38	.078	99.17	773	34678	97.70	796	161	100	21887	.2	21715
3.0	2192	38	.058	99.42	1499	67176	98.49	1011	167	100	43108	.2	42776

S=20% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT .

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 80 PCF, WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.18
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 80 PCF WATER CONT.= 37.7% C/L=.0076 L=4124 KF=1.18

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 20%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
FT	F-DEG*DAYS		PROB.		--------- YEARS	------------				%	YEARS	FT	YEARS
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	244	38	.998	0.22	1	42	0.02	42	42	0	4	.3	4
1.1	295	38	.991	0.91	1	46	0.07	46	46	0	5	.3	5
1.2	351	38	.974	2.71	1	51	0.25	51	50	100	5	.3	5
1.3	412	38	.940	6.31	1	57	0.67	57	54	100	6	.3	6
1.4	477	38	.890	12.25	1	64	1.60	63	58	100	7	.3	7
1.5	548	38	.825	20.70	1	72	3.38	69	63	100	9	.3	9
1.6	624	38	.752	31.29	1	83	6.51	78	67	100	13	.3	13
1.7	704	38	.679	43.16	2	99	11.56	87	71	100	19	.3	18
1.8	789	38	.609	55.15	2	122	19.02	99	75	100	29	.2	28
1.9	879	38	.544	66.14	3	158	28.73	113	79	100	43	.2	43
2.0	974	38	.483	75.37	5	215	40.10	129	83	100	70	.2	69
2.1	1074	38	.425	82.60	7	308	52.14	147	88	100	117	.2	116
2.2	1179	38	.368	87.96	12	467	63.67	169	92	100	201	.2	200
2.3	1288	38	.314	91.77	20	746	73.69	196	96	100	357	.2	355
2.4	1403	38	.262	94.41	35	1250	81.66	229	100	100	650	.2	645
2.5	1522	38	.215	96.21	63	2177	87.59	270	104	100	1205	.2	1195
2.6	1646	38	.172	97.43	115	3917	91.77	322	108	100	2273	.2	2254
2.7	1776	38	.135	98.25	213	7225	94.61	390	112	100	4345	.2	4309
2.8	1909	38	.104	98.80	403	13599	96.48	478	117	100	8404	.2	8336
2.9	2048	38	.078	99.17	773	26009	97.70	597	121	100	16415	.2	16286
3.0	2192	38	.058	99.42	1499	50382	98.49	759	125	100	32331	.2	32082

S=20% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

```
H1  = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)             KU=0.81
      FROZEN DRY DENS. =  80 PCF, WATER CONT.= 37.7% C/L=.0076  L=4124  KF=1.18
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3  = WASE PILE OF SOIL--HAVING:
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)             KU=0.81
      FROZEN DRY DENS. =  80 PCF  WATER CONT.= 37.7% C/L=.0076  L=4124  KF=1.18
```

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 20%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

```
FPY    = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
         CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
         CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
            LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
    ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
            R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS
```

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WASTEPILE
FT	F-DEG*DAYS		PROB.		--------- YEARS		------------		%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	244	38	.998	0.22	1	34	0.02	34	33	0	4	.3	4
1.1	295	38	.991	0.91	1	37	0.07	37	37	0	4	.3	4
1.2	351	38	.974	2.71	1	41	0.25	41	40	0	4	.3	4
1.3	412	38	.940	6.31	1	46	0.67	45	43	0	5	.3	5
1.4	477	38	.890	12.25	1	51	1.60	50	47	66	6	.3	6
1.5	548	38	.825	20.70	1	58	3.38	56	50	100	7	.3	7
1.6	624	38	.752	31.29	1	66	6.51	62	53	100	10	.3	10
1.7	704	38	.679	43.16	2	79	11.56	70	57	100	15	.3	15
1.8	789	38	.609	55.15	2	98	19.02	79	60	100	23	.2	22
1.9	879	38	.544	66.14	3	126	29.73	90	63	100	35	.2	34
2.0	974	38	.463	75.37	5	172	40.10	103	67	100	56	.2	55
2.1	1074	38	.425	82.60	7	246	52.14	118	70	100	93	.2	92
2.2	1179	38	.368	87.96	12	373	63.67	136	73	100	161	.2	160
2.3	1288	38	.314	91.77	20	597	73.68	157	77	100	286	.2	284
2.4	1403	38	.262	94.41	35	1000	81.66	183	80	100	520	.2	516
2.5	1522	38	.215	96.21	63	1742	87.59	216	83	100	964	.2	956
2.6	1646	38	.172	97.43	115	3133	91.77	258	87	100	1818	.2	1803
2.7	1776	38	.135	98.25	213	5780	94.61	312	90	100	3476	.2	3448
2.8	1909	38	.104	98.80	403	10879	96.48	383	93	100	6723	.2	6669
2.9	2048	38	.078	99.17	773	20807	97.70	478	97	100	13132	.2	13029
3.0	2192	38	.058	99.42	1499	40305	98.49	607	100	100	25865	.2	25665

S=30% F=0.10

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

```
H1  = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)             KU=0.81
      FROZEN DRY DENS. =  70 PCF, WATER CONT.= 47.9% C/L=.0068  L=4590   KF=1.23
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3  = WASE PILE OF SOIL--HAVING:
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)             KU=0.81
      FROZEN DRY DENS. =  70 PCF  WATER CONT.= 47.9% C/L=.0068  L=4590   KF=1.23

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%,          95% OF MAX L
   HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
   LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY    = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROFS IN H3) BUT
         CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
         CONSERVATIVE FOR ALL OBJECTS HAVING (X-A) <  0.30 FT
FOR H1=TCT:  UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
             LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
       ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
             R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS
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					COVER THERMAL PROPERTIES IN H3 (R1.3=1)							WASTEPILE
FT	F-DEG*DAYS		PROB.		--------- YEARS ------------				%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	305	38	.989	1.15	1	114	0.10	113	111	100	13	.3	13
1.1	369	38	.965	3.60	1	128	0.36	127	122	100	15	.3	15
1.2	439	38	.921	8.55	1	144	1.05	143	133	100	18	.3	18
1.3	515	38	.855	16.58	1	166	2.60	161	144	100	24	.3	24
1.4	598	38	.777	27.56	1	195	5.66	184	156	100	34	.3	34
1.5	686	38	.695	40.57	2	238	11.06	212	167	100	52	.2	51
1.6	781	38	.616	54.04	2	304	19.22	246	178	100	80	.2	79
1.7	881	38	.543	66.38	3	409	30.09	266	187	100	130	.2	129
1.8	988	38	.474	76.53	5	585	42.98	334	200	100	224	.2	221
1.9	1101	38	.410	84.18	8	899	56.40	392	211	100	404	.2	400
2.0	1220	38	.347	89.57	15	1480	68.68	463	222	100	757	.2	749
2.1	1345	38	.288	93.22	27	2591	78.67	553	233	100	1466	.2	1451
2.2	1476	38	.232	95.61	50	4780	86.06	666	244	100	2912	.2	2882
2.3	1613	38	.183	97.15	98	9191	91.14	814	256	100	5909	.2	5848
2.4	1757	38	.140	98.15	195	18247	94.46	1011	267	100	12203	.2	12079
2.5	1906	38	.104	98.79	397	37133	96.55	1280	278	100	25563	.2	25314
2.6	2062	38	.076	99.20	823	76921	97.85	1652	289	100	54009	.1	53687
2.7	2223	38	.054	99.46	1730	161269	98.65	2175	300	100	114686	.1	114405
2.8	2391	38	.038	99.64	3678	341553	99.14	2925	311	100	245581	.1	245291
2.9	2565	38	.026	99.75	7894	730132	99.45	4019	322	100	531279	.1	530035
3.0	2745	38	.017	99.83	17070	1573341	99.64	5642	333	100	1155136	.1	1152502

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF, WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT H1	F-DEG*DAYS TC AVG	& CV%	PROB. FP AVG	& CV%	COVER THERMAL PROPERTIES IN H3 (R1.3=1) — YEARS FPY	UP.YRS	CV%	LBOND	ABD	% R50	YEARS DELTA	FT H3M	WASTEPILE YEARS DELTA
1.0	305	38	.989	1.15	1	57	0.10	57	56	100	7	.3	7
1.1	369	38	.965	3.60	1	64	0.36	64	61	100	8	.3	7
1.2	439	38	.921	8.55	1	72	1.05	71	67	100	9	.3	9
1.3	515	38	.855	16.58	1	83	2.60	81	72	100	12	.3	12
1.4	598	38	.777	27.56	1	97	5.66	92	78	100	17	.3	17
1.5	686	38	.695	40.57	2	119	11.06	106	83	100	26	.2	26
1.6	781	38	.616	54.04	2	152	19.22	123	89	100	40	.2	39
1.7	881	38	.543	66.39	3	204	30.09	143	94	100	65	.2	64
1.8	988	38	.474	76.53	5	293	42.98	167	100	100	112	.2	111
1.9	1101	38	.410	84.18	8	450	56.40	196	106	100	202	.2	200
2.0	1220	38	.347	89.57	15	740	68.68	232	111	100	379	.2	375
2.1	1345	38	.288	93.22	27	1296	78.67	276	117	100	733	.2	725
2.2	1476	38	.232	95.61	50	2390	86.06	333	122	100	1456	.2	1441
2.3	1613	38	.183	97.15	98	4595	91.14	407	128	100	2955	.2	2924
2.4	1757	38	.140	98.15	195	9123	94.46	506	133	100	6102	.2	6040
2.5	1906	38	.104	98.79	397	18566	96.55	640	139	100	12784	.2	12657
2.6	2062	38	.076	99.20	823	38461	97.85	826	144	100	27004	.1	26843
2.7	2223	38	.054	99.46	1730	80635	98.65	1088	150	100	57343	.1	57203
2.8	2391	38	.038	99.64	3678	170776	99.14	1463	156	100	122940	.1	122646
2.9	2565	38	.026	99.75	7894	365066	99.45	2010	161	100	265640	.1	265017
3.0	2745	38	.017	99.83	17070	786671	99.64	2821	167	100	577569	.1	576251

S=30% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

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FROZEN DRY DENS. = 70 PCF, WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
LAMBDA*SORIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
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CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERVATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS ------------					%	YEARS	FT	YEARS
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	305	38	.989	1.15	1	38	0.10	38	37	0	4	.3	4
1.1	369	38	.965	3.60	1	43	0.36	42	41	0	5	.3	5
1.2	439	38	.921	8.55	1	48	1.05	48	44	0	6	.3	6
1.3	515	38	.855	16.53	1	55	2.60	54	48	100	8	.3	8
1.4	598	38	.777	27.56	1	65	5.66	61	52	100	11	.3	11
1.5	686	38	.695	40.57	2	79	11.06	71	56	100	17	.2	17
1.6	781	38	.616	54.04	2	101	19.22	82	59	100	27	.2	26
1.7	881	38	.543	66.38	3	136	30.09	95	63	100	43	.2	43
1.8	988	38	.474	76.53	5	195	42.98	111	67	100	75	.2	74
1.9	1101	38	.410	84.18	8	300	56.40	131	70	100	135	.2	133
2.0	1220	38	.347	89.57	15	493	68.68	154	74	100	252	.2	250
2.1	1345	38	.288	93.22	27	864	78.67	184	78	100	489	.2	484
2.2	1476	38	.232	95.61	50	1593	86.06	222	81	100	971	.2	961
2.3	1613	38	.183	97.15	98	3064	91.14	271	85	100	1970	.2	1949
2.4	1757	38	.140	98.15	195	6082	94.46	337	89	100	4068	.2	4026
2.5	1906	38	.104	98.79	397	12378	96.55	427	93	100	8523	.2	8438
2.6	2062	38	.076	99.20	823	25640	97.85	551	96	100	18003	.1	17896
2.7	2223	38	.054	99.46	1730	53756	98.65	725	100	100	38229	.1	38135
2.8	2391	38	.038	99.64	3678	113851	99.14	975	104	100	81960	.1	81764
2.9	2565	38	.026	99.75	7894	243377	99.45	1340	107	100	177093	.1	176678
3.0	2745	38	.017	99.83	17070	524447	99.64	1891	111	100	385046	.1	384167

S=30% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF, WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LAMBDA*SQRT[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
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CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
FT	F-DEG*DAYS		PROB.		--------- YEARS	------------				%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	305	38	.989	1.15	1	28	0.10	28	28	0	3	.3	
1.1	369	38	.965	3.60	1	32	0.36	32	31	0	4	.3	4
1.2	439	38	.921	8.55	1	36	1.05	36	33	0	5	.3	5
1.3	515	38	.855	16.58	1	41	2.60	40	36	0	6	.3	6
1.4	598	38	.777	27.56	1	49	5.66	46	39	32	9	.3	8
1.5	686	38	.695	40.57	2	60	11.06	53	42	93	13	.2	13
1.6	781	38	.616	54.04	2	76	19.22	61	44	98	20	.2	20
1.7	881	38	.543	66.38	3	102	30.09	71	47	99	32	.2	32
1.8	988	38	.474	76.53	5	146	42.98	83	50	100	56	.2	55
1.9	1101	38	.410	84.18	8	225	56.40	98	53	100	101	.2	100
2.0	1220	38	.347	89.57	15	370	68.68	116	56	100	189	.2	187
2.1	1345	38	.288	93.22	27	648	78.67	138	58	100	366	.2	363
2.2	1476	38	.232	95.61	50	1195	86.06	167	61	100	728	.2	720
2.3	1613	38	.183	97.15	98	2298	91.14	204	64	100	1477	.2	1462
2.4	1757	38	.140	98.15	195	4562	94.46	253	67	100	3051	.2	3020
2.5	1906	38	.104	98.79	397	9293	96.55	320	69	100	6392	.2	6328
2.6	2062	38	.076	99.20	823	19230	97.85	413	72	100	13502	.1	13422
2.7	2223	38	.054	99.46	1730	40317	98.65	544	75	100	28672	.1	28601
2.8	2391	38	.038	99.64	3678	85368	99.14	731	78	100	61470	.1	61323
2.9	2565	38	.026	99.75	7894	182533	99.45	1005	81	100	132820	.1	132509
3.0	2745	38	.017	99.83	17070	393335	99.64	1411	83	100	288785	.1	288125

S=30% F=0.50

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF, WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 70 PCF WATER CONT.= 47.9% C/L=.0068 L=4590 KF=1.23

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 30%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SORT[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT H1	F-DEG*DAYS TCAVG&CV%		PROB. FFAVG&CV%		COVER THERMAL PROPERTIES IN H3 (R1.3=1) FPY	UP.YRS	CV%	LBOND	ABD	% R50	YEARS DELTA	FT H3M	WASTEPILE YEARS DELTA
1.0	305	38	.989	1.15	1	23	0.10	23	22	0	3	.3	3
1.1	369	38	.965	3.60	1	26	0.36	25	24	0	3	.3	3
1.2	439	38	.921	8.55	1	29	1.05	29	27	0	4	.3	4
1.3	515	38	.855	16.58	1	33	2.60	32	29	0	5	.3	5
1.4	598	38	.777	27.56	1	39	5.66	37	31	0	7	.3	7
1.5	686	38	.695	40.57	2	48	11.06	42	33	33	10	.2	10
1.6	721	38	.616	54.04	2	61	19.22	49	36	84	16	.2	16
1.7	861	38	.543	66.38	3	82	30.09	57	38	94	26	.2	26
1.8	966	38	.474	76.53	5	117	42.98	67	40	97	45	.2	44
1.9	1101	38	.410	84.18	8	180	56.40	78	42	99	81	.2	80
2.0	1220	38	.347	89.57	15	296	68.68	93	44	99	151	.2	150
2.1	1345	38	.288	93.22	27	518	78.67	111	47	100	293	.2	290
2.2	1476	38	.232	95.61	50	956	86.06	133	49	100	582	.2	576
2.3	1613	38	.183	97.15	98	1838	91.14	163	51	100	1182	.2	1170
2.4	1757	38	.140	98.15	195	3649	94.46	202	53	100	2441	.2	2416
2.5	1906	38	.104	98.79	397	7427	96.55	256	56	100	5114	.2	5063
2.6	2062	38	.076	99.20	823	15384	97.85	330	58	100	10802	.1	10737
2.7	2223	38	.054	99.46	1730	32254	98.65	435	60	100	22937	.1	22881
2.8	2391	38	.038	99.64	3678	68311	99.14	585	62	100	49176	.1	49058
2.9	2565	38	.026	99.75	7894	146027	99.45	804	64	100	106256	.1	106007
3.0	2745	38	.017	99.83	17070	314668	99.64	1128	67	100	231028	.1	230500

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
  UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.8.
  FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
  UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
  FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
  HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
  LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
  CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
  CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVE
  LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
  ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
  R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS			------------		%	YEARS	FT	YEARS
H1	TCAVG&	CV%	FPAVG&	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	367	38	.966	3.48	1	88	0.36	85	83	100	12	.3	1
1.1	444	38	.917	8.97	1	101	1.18	100	92	100	15	.3	15
1.2	528	38	.843	18.17	1	119	3.17	116	100	100	21	.3	2
1.3	620	38	.756	30.78	1	146	7.27	135	108	100	32	.2	3
1.4	719	38	.666	45.38	2	186	14.27	160	117	100	49	.2	48
1.5	825	38	.582	59.83	3	251	24.64	189	125	100	81	.2	80
1.6	939	38	.505	72.25	4	363	38.00	225	133	100	144	.2	14
1.7	1060	38	.432	81.74	7	572	52.75	270	142	100	273	.2	26
1.8	1189	38	.363	88.37	13	979	66.63	327	150	100	541	.2	534
1.9	1324	38	.297	92.73	24	1807	77.94	399	158	100	1115	.2	110
2.0	1468	38	.236	95.48	48	3536	86.08	492	167	100	2342	.1	233
2.1	1618	38	.181	97.19	100	7204	91.46	615	175	100	4995	.1	4926
2.2	1776	38	.135	98.25	213	15161	94.85	781	183	100	10918	.1	10884
2.3	1941	38	.097	98.90	468	32791	96.92	1011	192	100	24343	.1	2426
2.4	2113	38	.068	99.30	1045	72542	98.15	1340	200	100	55159	.1	5499
2.5	2293	38	.047	99.55	2371	163431	98.89	1820	208	100	126619	.1	126250
2.6	2480	38	.031	99.71	5450	373591	99.32	2540	217	100	293700	.1	29286
2.7	2675	38	.020	99.81	12655	863880	99.58	3641	225	100	686879	.1	68496
2.8	2876	38	.013	99.87	29623	2015668	99.73	5357	233	100	1616696	.1	1612355
2.9	3085	38	.008	99.91	69773	4735770	99.83	8078	242	100	3823509	.1	3813525
3.0	3302	38	.005	99.94	165107	11184500	99.89	12457	250	100	9073945	.1	905095

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)   KU=0.81
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASTE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)   KU=0.81
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%,   95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 FROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
AED = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS	------------				%	YEARS	FT	YEARS
H1	TCAVG&	CV%	FPAVG&	CV%	FPY	UP.YRS	CV%	LBOND	AED	R50	DELTA	H3M	DELTA
1.0	367	38	.966	3.46	1	44	0.36	44	42	0	6	.3	6
1.1	444	38	.917	8.97	1	51	1.18	50	46	86	8	.3	7
1.2	528	38	.843	18.17	1	60	3.17	58	50	100	11	.3	10
1.3	620	38	.756	30.78	1	73	7.27	68	54	100	16	.2	16
1.4	719	38	.666	45.38	2	93	14.27	80	58	100	24	.2	24
1.5	825	38	.582	59.83	3	125	24.64	95	63	100	40	.2	40
1.6	939	38	.505	72.25	4	182	38.00	113	67	100	72	.2	71
1.7	1060	38	.432	81.74	7	286	52.75	135	71	100	136	.2	135
1.8	1189	38	.363	88.37	13	489	66.63	163	75	100	271	.2	267
1.9	1324	38	.297	92.73	24	903	77.94	199	79	100	558	.2	551
2.0	1468	38	.236	95.48	48	1768	86.08	246	83	100	1171	.1	1167
2.1	1618	38	.181	97.19	100	3602	91.46	308	88	100	2498	.1	2491
2.2	1776	38	.135	98.25	213	7580	94.85	390	92	100	5459	.1	5442
2.3	1941	38	.097	98.90	468	16396	96.92	506	96	100	12172	.1	12134
2.4	2113	38	.068	99.30	1045	36271	98.15	670	100	100	27579	.1	27497
2.5	2293	38	.047	99.55	2371	81716	98.89	910	104	100	63310	.1	63125
2.6	2480	38	.031	99.71	5450	186796	99.32	1270	108	100	146850	.1	146433
2.7	2675	38	.020	99.81	12655	431940	99.58	1821	112	100	343439	.1	342490
2.8	2876	38	.013	99.87	29623	1007834	99.73	2679	117	100	808348	.1	806179
2.9	3085	38	.008	99.91	69773	2367885	99.83	4039	121	100	1911754	.1	1906763
3.0	3302	38	.005	99.94	165107	5592249	99.89	6228	125	100	4536973	.1	4525477

S=40% F=0.30

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
LAMBDA*SQRT[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
FT	F-DEG*DAYS		PROB.		--------- YEARS	------------			%	YEARS	FT		YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	347	38	.966	3.48	1	29	0.36	29	28	0	4	.3	4
1.1	444	38	.917	8.97	1	34	1.18	33	31	0	5	.3	5
1.2	528	38	.843	18.17	1	40	3.17	39	33	0	7	.3	7
1.3	620	38	.756	30.78	1	49	7.27	45	36	35	11	.2	10
1.4	719	38	.666	45.38	2	62	14.27	53	39	92	16	.2	16
1.5	825	38	.582	59.83	3	84	24.64	63	42	97	27	.2	27
1.6	939	38	.505	72.25	4	121	38.00	75	44	99	48	.2	48
1.7	1060	38	.432	81.74	7	191	52.75	90	47	100	91	.2	90
1.8	1189	38	.363	88.37	13	326	66.63	109	50	100	180	.2	178
1.9	1324	38	.297	92.73	24	602	77.94	133	53	100	372	.2	367
2.0	1468	38	.236	95.48	48	1179	86.08	164	56	100	781	.1	778
2.1	1618	38	.181	97.19	100	2401	91.46	205	58	100	1665	.1	1660
2.2	1776	38	.135	98.25	213	5054	94.85	260	61	100	3639	.1	3628
2.3	1941	38	.097	98.90	468	10930	96.92	337	64	100	8114	.1	8090
2.4	2113	38	.068	99.30	1045	24181	98.15	447	67	100	18386	.1	18331
2.5	2293	38	.047	99.55	2371	54477	98.89	607	69	100	42206	.1	42083
2.6	2480	38	.031	99.71	5450	124530	99.32	847	72	100	97960	.1	97622
2.7	2675	38	.020	99.81	12655	287960	99.58	1214	75	100	228960	.1	228327
2.8	2876	38	.013	99.87	29623	671889	99.73	1786	78	100	539899	.1	537452
2.9	3085	38	.008	99.91	69773	1578590	99.83	2693	81	100	1274503	.1	1271175
3.0	3302	38	.005	99.94	165107	3728166	99.89	4152	83	100	3024649	.1	3016985

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UFFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
LANSDA*SORIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS			------------		%	YEARS	FT	YEARS
H1	TCAVG&CV%		FFAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	367	38	.966	3.48	1	22	0.36	22	21	0	3	.3	3
1.1	444	38	.917	8.97	1	25	1.18	25	23	0	4	.3	4
1.2	528	38	.843	18.17	1	30	3.17	29	25	0	5	.3	5
1.3	620	38	.756	30.78	1	36	7.27	34	27	0	8	.2	8
1.4	719	38	.666	45.38	2	47	14.27	40	29	30	12	.2	12
1.5	825	38	.582	59.83	3	63	24.64	47	31	61	20	.2	20
1.6	939	38	.505	72.25	4	91	38.00	56	33	93	36	.2	36
1.7	1060	38	.432	81.74	7	143	52.75	69	35	97	68	.2	67
1.8	1189	38	.363	88.37	13	245	66.63	82	38	99	135	.2	134
1.9	1324	38	.297	92.73	24	452	77.94	100	40	99	279	.2	275
2.0	1468	38	.236	95.48	48	884	86.08	123	42	100	586	.1	584
2.1	1618	38	.181	97.19	100	1801	91.46	154	44	100	1249	.1	1245
2.2	1776	38	.135	98.25	213	3790	94.85	195	46	100	2729	.1	2721
2.3	1941	38	.097	98.90	468	8198	96.92	253	48	100	6086	.1	6067
2.4	2113	38	.068	99.30	1045	18136	98.15	335	50	100	13790	.1	13748
2.5	2293	38	.047	99.55	2371	40858	98.89	455	52	100	31655	.1	31563
2.6	2480	38	.031	99.71	5450	93398	99.32	635	54	100	73425	.1	73216
2.7	2675	38	.020	99.81	12655	215970	99.58	910	56	100	171720	.1	171245
2.8	2876	38	.013	99.87	29623	503917	99.73	1339	58	100	404174	.1	403089
2.9	3085	38	.008	99.91	69773	1183943	99.83	2019	60	100	955877	.1	953321
3.0	3302	38	.005	99.94	165107	2796124	99.89	3114	62	100	2268486	.1	2262739

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-198
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.36

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOI
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.8
FROZEN DRY DENS. = 60 PCF, WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.9
FROZEN DRY DENS. = 60 PCF WATER CONT.= 61.6% C/L=.0062 L=5057 KF=1.30

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 40%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SOFIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROFS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERVATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVE
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILL
					---------- YEARS			------------		%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	367	38	.966	3.48	1	18	0.36	18	17	0	2	.3	[illegible]
1.1	444	38	.917	8.97	1	20	1.18	20	18	0	3	.3	3
1.2	522	38	.843	18.17	1	24	3.17	23	20	0	4	.3	4
1.3	620	38	.756	30.78	1	29	7.27	27	22	0	6	.2	[illegible]
1.4	719	38	.666	45.38	2	37	14.27	32	23	1	10	.2	10
1.5	825	38	.562	59.83	3	50	24.64	38	25	52	16	.2	16
1.6	939	38	.505	72.25	4	73	38.00	45	27	83	29	.2	29
1.7	1060	38	.432	81.74	7	114	52.75	54	28	93	55	.2	54
1.8	1189	38	.363	88.37	13	196	66.63	65	30	97	108	.2	107
1.9	1324	38	.297	92.73	24	361	77.94	80	32	98	223	.2	220
2.0	1468	38	.236	95.48	48	707	86.08	98	33	99	468	.1	467
2.1	1618	38	.181	97.19	100	1441	91.46	123	35	100	999	.1	99[illegible]
2.2	1776	38	.135	98.25	213	3032	94.85	156	37	100	2184	.1	2177
2.3	1941	38	.097	98.90	468	6558	96.92	202	39	100	4869	.1	4854
2.4	2113	38	.068	99.30	1045	14502	98.15	268	40	100	11032	.1	10999
2.5	2293	38	.047	99.55	2371	32686	98.89	364	42	100	25324	.1	25250
2.6	2488	38	.031	99.71	5450	74718	99.32	508	43	100	58740	.1	58573
2.7	2675	38	.020	99.81	12655	172776	99.58	728	45	100	137376	.1	13699[illegible]
2.8	2876	38	.013	99.87	29623	403134	99.73	1071	47	100	323339	.1	322471
2.9	3085	38	.008	99.91	69773	947154	99.83	1616	48	100	764702	.1	762705
3.0	3302	38	.005	99.94	165107	2236900	99.89	2491	50	100	1814789	.1	1810191

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THERMAL AND UPFREEZING ANALYSIS ESTIMATES  --  PROGRAM UPFREEZ5X -- 10-31-1986
            MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
 ****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) =  0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1  = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)          KU=0.81
      FROZEN DRY DENS. =  50 PCF, WATER CONT.= 80.7% C/L=.0057  L=5523  KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3  = WASE PILE OF SOIL--HAVING:
      UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT)          KU=0.81
      FROZEN DRY DENS. =  50 PCF  WATER CONT.= 80.7% C/L=.0057  L=5523  KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%,          95% OF MAX L
   HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.10,
   LAMBDA*SQRT[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY   = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
         CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
         CONSERATIVE FOR ALL OBJECTS HAVING (X-A) <  0.30 FT
FOR H1=TCT:  UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
             LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
       ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
             R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS
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FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					YEARS					%	YEARS	FT	YEARS
H1	TCAVG	CV%	FPAVG	CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	423	38	.933	7.17	1	74	0.93	73	67	100	12	.3	12
1.1	512	38	.859	16.11	1	88	2.82	86	73	100	17	.3	17
1.2	609	38	.766	29.15	1	109	6.94	102	80	100	26	.2	25
1.3	715	38	.670	44.72	2	143	14.34	122	87	100	41	.2	40
1.4	829	38	.580	60.23	3	199	25.67	148	93	100	71	.2	70
1.5	951	38	.497	73.37	4	301	40.36	180	100	100	134	.2	132
1.6	1082	38	.420	83.10	8	503	56.21	220	107	100	270	.2	266
1.7	1222	38	.346	89.64	15	919	70.40	272	113	100	563	.1	561
1.8	1370	38	.277	93.76	30	1801	81.19	339	120	100	1199	.1	1194
1.9	1526	38	.213	96.26	64	3727	88.58	426	127	100	2655	.1	2645
2.0	1691	38	.158	97.75	142	8089	93.28	544	133	100	6069	.1	6047
2.1	1865	38	.113	98.64	326	18238	96.11	709	140	100	14229	.1	14178
2.2	2046	38	.078	99.16	766	42373	97.76	948	147	100	34042	.1	33924
2.3	2237	38	.053	99.48	1837	100776	98.71	1304	153	100	82763	.1	82484
2.4	2435	38	.034	99.67	4473	244049	99.24	1851	160	100	203783	.1	203113
2.5	2642	38	.022	99.79	11029	599310	99.55	2710	167	100	506741	.1	505125
2.6	2858	38	.014	99.87	27454	1487504	99.73	4090	173	100	1269646	.1	1265715
2.7	3082	38	.008	99.91	68844	3721789	99.83	6351	180	100	3198924	.1	3189307
2.8	3315	38	.005	99.94	173571	9366943	99.89	10119	187	100	8091385	.1	8067859
2.9	3556	38	.003	99.96	439261	23671590	99.93	16502	193	100	%20517900	.1	%20460030
3.0	3805	38	.002	99.97	%1114284	50600850	99.95	24961	200	100	%33340640	.3	%3340870

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5% -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOI
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.8
FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.20,
LAMBDA*SQRIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BU
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVE
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)									WASTEPILE
					---------- YEARS			----------		%	YEARS	FT		YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M		DELTA
1.0	423	38	.933	7.17	1	37	0.93	36	33	0	6	.3		
1.1	512	38	.859	16.11	1	44	2.82	43	37	0	8	.3		8
1.2	609	38	.766	29.15	1	55	6.94	51	40	89	13	.2		13
1.3	715	38	.670	44.72	2	71	14.34	61	43	98	20	.2		20
1.4	829	38	.580	60.23	3	99	25.67	74	47	99	36	.2		35
1.5	951	38	.497	73.37	4	151	40.36	90	50	100	67	.2		66
1.6	1082	38	.420	83.10	8	251	56.21	110	53	100	135	.2		133
1.7	1222	38	.346	89.64	15	460	70.40	136	57	100	282	.1		281
1.8	1370	38	.277	93.76	30	900	81.19	169	60	100	599	.1		597
1.9	1526	38	.213	96.26	64	1864	88.58	213	63	100	1327	.1		1323
2.0	1691	38	.158	97.75	142	4044	93.28	272	67	100	3034	.1		3023
2.1	1865	38	.113	98.64	326	9119	96.11	354	70	100	7114	.1		7089
2.2	2046	38	.078	99.16	766	21186	97.76	474	73	100	17021	.1		16962
2.3	2237	38	.053	99.48	1837	50338	98.71	652	77	100	41392	.1		41242
2.4	2435	38	.034	99.67	4473	122024	99.24	926	80	100	101891	.1		101556
2.5	2642	38	.022	99.79	11029	299655	99.55	1355	83	100	253370	.1		252563
2.6	2858	38	.014	99.87	27454	743752	99.73	2045	87	100	634823	.1		632857
2.7	3082	38	.008	99.91	68844	1860894	99.83	3175	90	100	1599462	.1		1594653
2.8	3315	38	.005	99.94	173571	4683472	99.89	5060	93	100	4045693	.1		4033929
2.9	3556	38	.003	99.96	439261	11835790	99.93	8251	97	100	%10258950	.1		%10230010
3.0	3805	38	.002	99.97	%1114284	25300430	99.95	12480	100	100	%16670320	.3		%1670440

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE FILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT
TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF WATER CONT.= 60.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.30,
LAMBDA*SORIN-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					--------- YEARS	------------				%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	423	38	.933	7.17	1	25	0.93	24	22	0	4	.3	4
1.1	512	38	.859	16.11	1	29	2.82	29	24	0	6	.3	6
1.2	609	38	.766	29.15	1	36	6.94	34	27	0	9	.2	8
1.3	715	38	.670	44.72	2	48	14.34	41	29	36	14	.2	13
1.4	829	38	.580	60.23	3	66	25.67	49	31	85	24	.2	2[illegible]
1.5	951	38	.497	73.37	4	100	40.36	60	33	94	45	.2	44
1.6	1082	38	.420	83.10	8	168	56.21	73	36	97	90	.2	89
1.7	1222	38	.346	89.64	15	306	70.40	91	38	99	188	.1	187
1.8	1370	38	.277	93.76	30	600	81.19	113	40	100	400	.1	398
1.9	1526	38	.213	96.26	64	1242	88.53	142	42	100	895	.1	882
2.0	1691	38	.158	97.75	142	2696	93.28	181	44	100	2023	.1	2016
2.1	1865	38	.113	98.64	326	6079	96.11	236	47	100	4743	.1	4726
2.2	2046	38	.078	99.16	766	14124	97.76	316	49	100	11347	.1	11308
2.3	2237	38	.053	99.48	1837	33592	98.71	435	51	100	27588	.1	27495
2.4	2435	38	.034	99.67	4473	81350	99.24	617	53	100	67928	.1	67704
2.5	2642	38	.022	99.79	11029	199770	99.55	903	56	100	168914	.1	168375
2.6	2858	38	.014	99.87	27454	495835	99.73	1363	58	100	423215	.1	421905
2.7	3082	38	.008	99.91	68844	1240596	99.83	2117	60	100	1066308	.1	1063102
2.8	3315	38	.005	99.94	173571	3122315	99.89	3373	62	100	2697129	.1	2689286
2.9	3556	38	.003	99.96	439261	7890529	99.93	5501	64	100	6839308	.1	6820009
3.0	3885	38	.002	99.97	%1114284	16866950	99.95	8320	67	100	%11113550	.3	%11

13620

S=50% F=0.40

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
    UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.8
    FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
    UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.8
    FROZEN DRY DENS. = 50 PCF WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
  HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.40,
  LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
    CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
    CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVE[R]
    LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
    ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
    R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

FT	F-DEG*DAYS		PROB.		COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
					---------- YEARS			----------		%	YEARS	FT	YEARS
H1	TCAVG	&CV%	FPAVG	&CV%	FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	423	38	.933	7.17	1	18	0.93	18	17	0	3	.3	.
1.1	512	38	.859	16.11	1	22	2.82	21	18	0	4	.3	4
1.2	609	38	.766	29.15	1	27	6.94	25	20	0	6	.2	[illegible]
1.3	715	38	.670	44.72	2	36	14.34	31	22	0	10	.2	1[illegible]
1.4	829	38	.580	60.23	3	50	25.67	37	23	50	18	.2	18
1.5	951	38	.497	73.37	4	75	40.36	45	25	84	33	.2	33
1.6	1082	38	.420	83.10	8	126	56.21	55	27	93	67	.2	6[illegible]
1.7	1222	38	.346	89.64	15	230	70.40	68	28	97	141	.1	14[illegible]
1.8	1370	38	.277	93.76	30	450	81.19	85	30	99	300	.1	299
1.9	1526	38	.213	96.26	64	932	88.58	106	32	99	664	.1	66[illegible]
2.0	1691	38	.158	97.75	142	2022	93.28	136	33	100	1517	.1	151[illegible]
2.1	1865	38	.113	98.64	326	4559	96.11	177	35	100	3557	.1	354[illegible]
2.2	2046	38	.078	99.16	766	10593	97.76	237	37	100	8510	.1	8481
2.3	2237	38	.053	99.48	1837	25194	98.71	326	38	100	20691	.1	2062[illegible]
2.4	2435	38	.034	99.67	4473	61012	99.24	463	40	100	50946	.1	5077[illegible]
2.5	2642	38	.022	99.79	11029	149828	99.55	678	42	100	126685	.1	126281
2.6	2858	38	.014	99.87	27454	371876	99.73	1023	43	100	317411	.1	316429
2.7	3082	38	.008	99.91	68844	930447	99.83	1588	45	100	799731	.1	79732[illegible]
2.8	3315	38	.005	99.94	173571	2341736	99.89	2530	47	100	2022846	.1	201696[illegible]
2.9	3556	38	.003	99.96	439261	5917897	99.93	4126	48	100	5129475	.1	5115087
3.0	3805	38	.002	99.97	%1114284	12650210	99.95	6240	50	100	6335168	.3	8335[illegible]
8													

THERMAL AND UPFREEZING ANALYSIS ESTIMATES -- PROGRAM UPFREEZ5X -- 10-31-1986
MANVILLE WAUKEGAN, ILL PLANT WASTE PILE
****** YEARS TO UPFREEZE OBJECTS THRU COVER -- PRELIMINARY RESULTS ******

OBJECTS HAVE (X - A) = 0.30 FT (EFFECTIVE PARTICLE SIZE, EPS.UF) STARTING AT TOP OF WASTE PILE--BOTTOM OF COVER OF TOTAL THICKNESS = TCT

THERMAL LOAD FREEZE INDEX (FI): LOGNORMAL W/ MEDIAN = 875 MEAN = 935 SD.LN=.365

H1 = DEPTH OF COVER ABOVE OBJECT, STARTING AT H1=TCT [FT] -- FINE-GRAINED SOIL
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF, WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42
H3M = OBJECT LENGTH FOR MAX UPFREEZE, STARTING IN:
H3 = WASE PILE OF SOIL--HAVING:
UNFROZEN DRY DENS.=100 PCF, WATER CONT.= 20.3% (80% SAT) KU=0.81
FROZEN DRY DENS. = 50 PCF WATER CONT.= 80.7% C/L=.0057 L=5523 KF=1.42

BOTH COVER AND WASTE PILE USE HEAVE STRAIN, S = 50%, 95% OF MAX L
HEAVE FRACTION NOT RECOVERED ON THAWING, F = 0.50,
LAMBDA*SQR[N-FACTOR] = .70 (AVG) .10 (SD)
ESTIMATES USE MOD. BERGGREN EQU. W/ KERSTEN KF'S AND + 25% - 25% ERROR IN KF'S
CORRELATION COEFFICIENT BETWEEN K1.F AND K3.F, R1.3=0.00

FPY = AVG YEARS TO FIRST FROST PENETRATION TO DEPTH H1 AND RETURN PERIOD
UP.YRS = ESTIMATED YEARS FOR OBJECT UPFREEZING FROM H1 (FOR H1 PROPS IN H3) BUT
CORRECT UP.YRS FOR DIFFERENCE IN DELTA'S WHEN OBJECT IN H3.
CONSERATIVE FOR ALL OBJECTS HAVING (X-A) < 0.30 FT
FOR H1=TCT: UP.YRS IS AN ESTIMATE (+ OR - CV%) OF YEARS TO UPFREEZE THRU COVER
LBOND = 1 STANDARD DEVIATION LOWER BOUND (LB),
ABD = ABOND = ABSOLUTE LB FOR HEAVE STRAIN, UNRECOVER FACTOR AND EPS.UF
R50 = ESTIMATED RELIABILITY (PROBABILITY) UP.YRS EXCEEDS 50 YEARS

					COVER THERMAL PROPERTIES IN H3 (R1.3=1)								WASTEPILE
FT	F-DEG*DAYS		PROB.		---------- YEARS	------------				%	YEARS	FT	YEARS
H1	TCAVG&CV%		FPAVG&CV%		FPY	UP.YRS	CV%	LBOND	ABD	R50	DELTA	H3M	DELTA
1.0	423	38	.933	7.17	1	15	0.93	15	13	0	2	.3	2
1.1	512	38	.859	16.11	1	18	2.82	17	15	0	3	.3	3
1.2	609	38	.766	29.15	1	22	6.94	20	16	0	5	.2	5
1.3	715	38	.670	44.72	2	29	14.34	24	17	0	8	.2	8
1.4	829	38	.580	60.23	3	40	25.67	30	19	16	14	.2	14
1.5	951	38	.497	73.37	4	60	40.36	36	20	70	27	.2	26
1.6	1082	38	.420	83.10	8	101	56.21	44	21	89	54	.2	53
1.7	1222	38	.346	89.64	15	184	70.40	54	23	95	113	.1	112
1.8	1370	38	.277	93.76	30	360	81.19	68	24	98	240	.1	239
1.9	1526	38	.213	96.26	64	745	88.58	85	25	99	531	.1	529
2.0	1691	38	.158	97.75	142	1618	93.28	109	27	100	1214	.1	1209
2.1	1865	38	.113	98.64	326	3648	96.11	142	28	100	2846	.1	2836
2.2	2046	38	.078	99.16	766	8475	97.76	190	29	100	6809	.1	6765
2.3	2237	38	.053	99.48	1837	20155	98.71	261	31	100	16553	.1	16497
2.4	2435	38	.034	99.67	4473	48810	99.24	370	32	100	40757	.1	40623
2.5	2642	38	.022	99.79	11029	119862	99.55	542	33	100	101348	.1	101025
2.6	2858	38	.014	99.87	27454	297501	99.73	818	35	100	253929	.1	253143
2.7	3082	38	.008	99.91	68844	744358	99.83	1270	36	100	639785	.1	637861
2.8	3315	38	.005	99.94	173571	1873389	99.89	2024	37	100	1618277	.1	1613572
2.9	3556	38	.003	99.96	439261	4734317	99.93	3300	39	100	4103580	.1	4092806
3.0	3805	38	.002	99.97	%1114284	10120170	99.95	4992	40	100	6668128	.3	666817

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UPFREEZ3 RUN COMPLETE